US008427928B2

# (12) United States Patent
**Nakata et al.**

(10) **Patent No.: US 8,427,928 B2**
(45) **Date of Patent: Apr. 23, 2013**

(54) **OPTICAL HEAD AND OPTICAL INFORMATION DEVICE**


(75) Inventors: **Hideki Nakata**, Kyoto (JP); **Kousei Sano**, Osaka (JP); **Takashi Haruguchi**, Fukuoka (JP); **Osamu Kajino**, Osaka (JP)

(73) Assignee: **Panasonic Corporation**, Osaka (JP)


(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 127 days.


(21) Appl. No.: **12/933,899**

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(86) PCT No.: **PCT/JP2010/000428**
§ 371 (c)(1), (2), (4) Date: **Sep. 22, 2010**

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PCT Pub. Date: **Jul. 29, 2010**

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(30) **Foreign Application Priority Data**

Jan. 26, 2009 (JP) ................................ 2009-014020

(51) **Int. Cl.**
*G11B 7/135* (2006.01)
*G11B 7/00* (2006.01)
*G11B 20/18* (2006.01)

(52) **U.S. Cl.**
USPC ................. **369/116**; 369/112.23; 369/112.26; 369/112.01

(58) **Field of Classification Search** ............. 369/112.11, 369/112.13, 112.23–112.26, 116, 118, 120; 720/681
See application file for complete search history.



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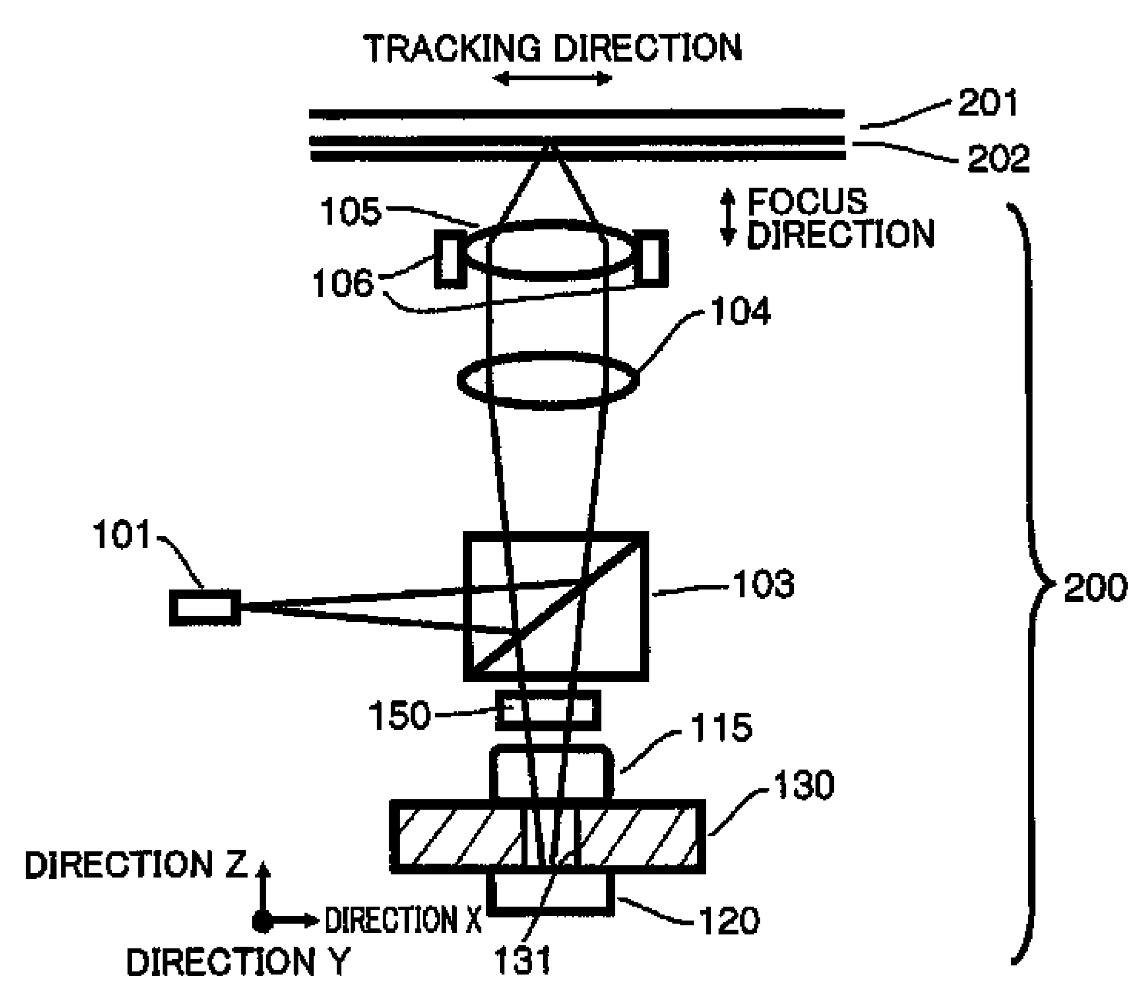
*Primary Examiner* — Wayne Young
*Assistant Examiner* — Dionne Pendleton
(74) *Attorney, Agent, or Firm* — Wenderoth, Lind & Ponack, L.L.P.


(57) **ABSTRACT**

An optical head **200** comprises: a light source **101** that emits a light beam; an objective lens **105** that condenses, in the form of converging light, the light beam emitted by the light source **101**, onto an information recording medium; a cylindrical lens **115** onto which a reflected light beam that is reflected by the information recording medium is incident, and which generates astigmatism for forming a focus error signal; a light detector **120** that receives the reflected light beam passing through the cylindrical lens **115**; and a holder **130** that holds the cylindrical lens **115** and the light detector **120**. The holder **130** has a first main face and a second main face that extend in directions that intersect the optical axis of the reflected light beam. The cylindrical lens **115** is bonded to the first main face and the light detector **120** is bonded to the second main face.


**13 Claims, 29 Drawing Sheets**



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| JP | 5-290404 | 11/1993 |
| JP | 10-3683 | 1/1998 |
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FIG.1

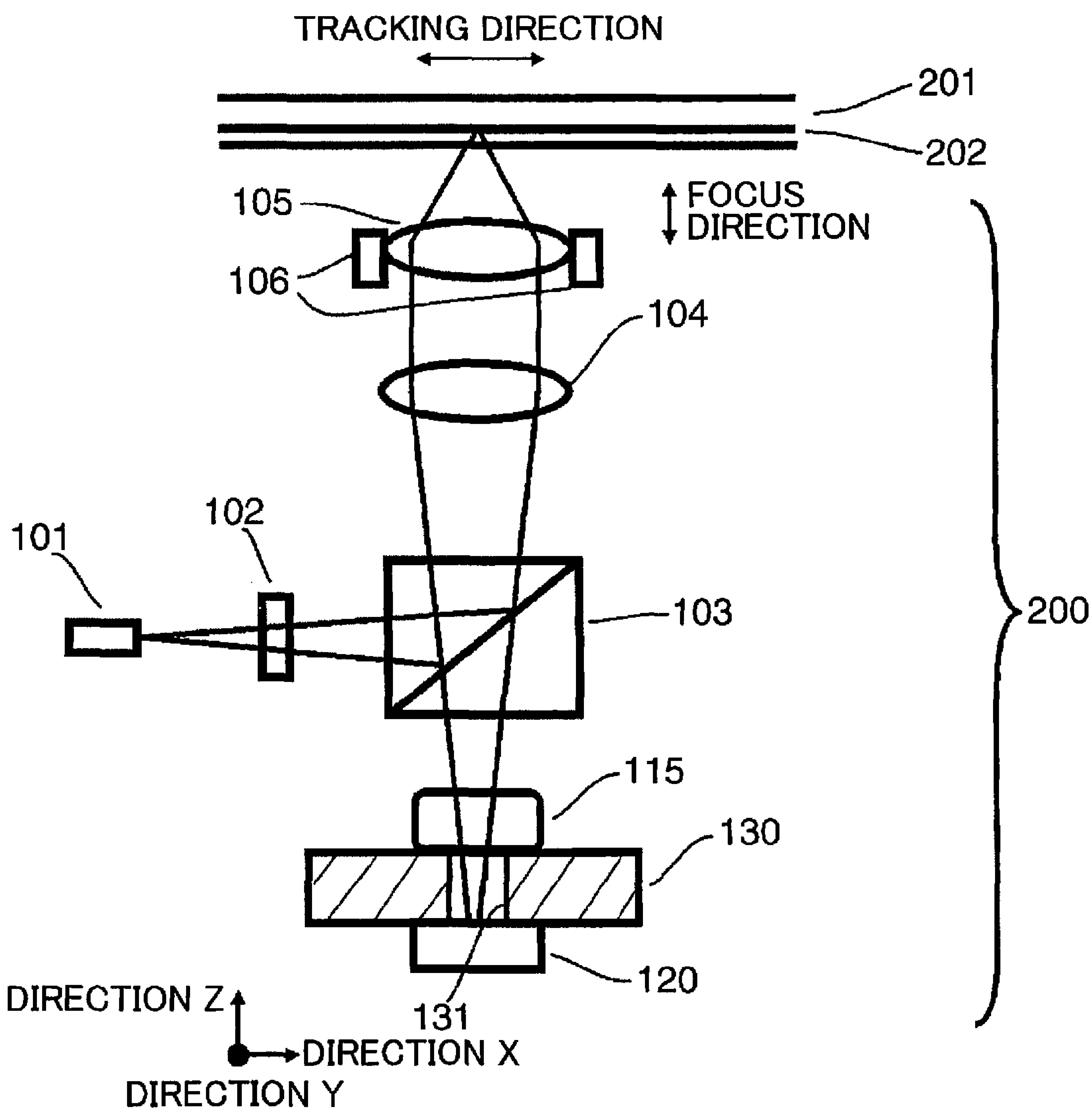

TRACKING DIRECTION
201
202
105
FOCUS DIRECTION
106
104
102
101
103
200
115
130
120
131
DIRECTION Z
DIRECTION X
DIRECTION Y

FIG.2A

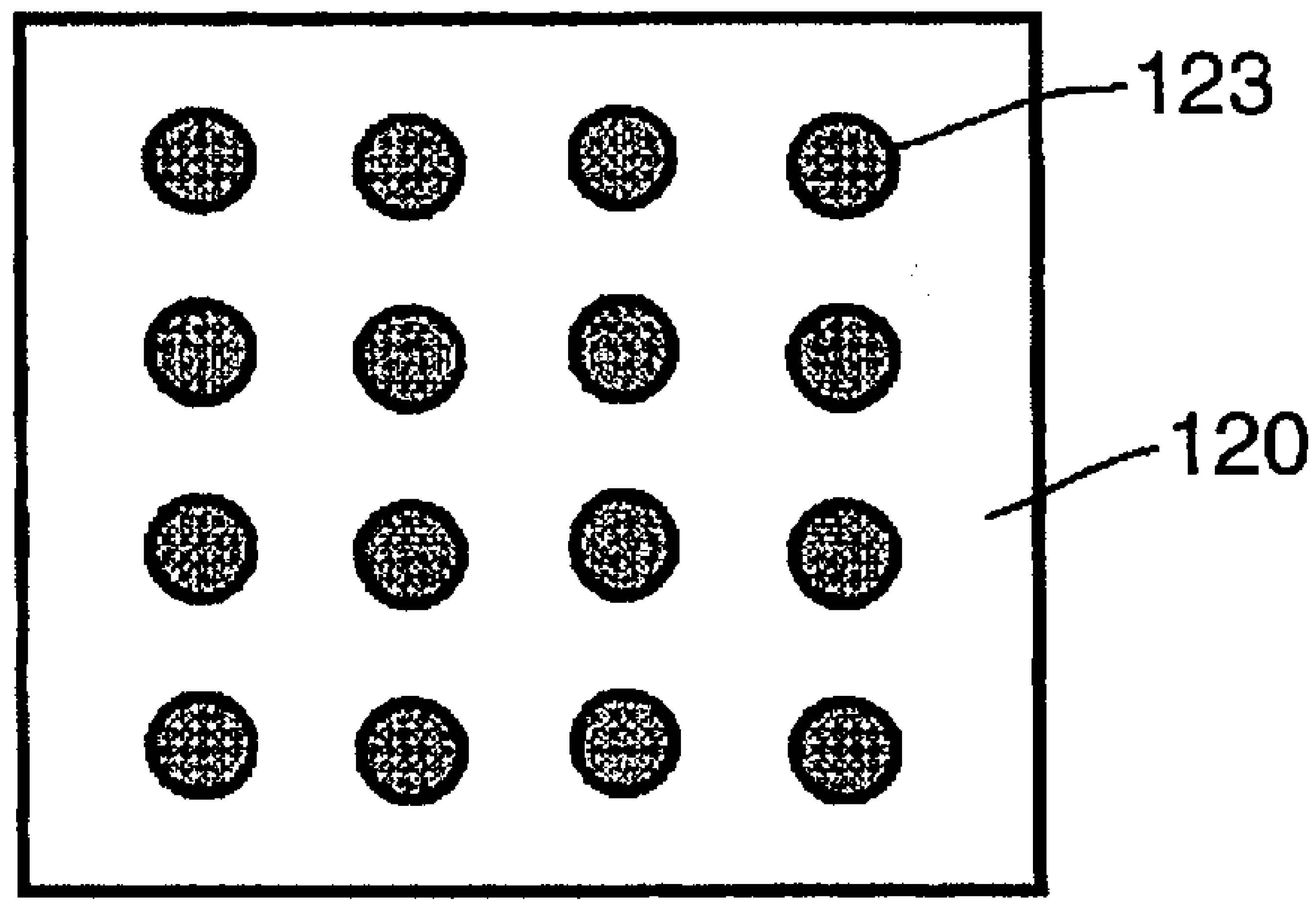



FIG.2B

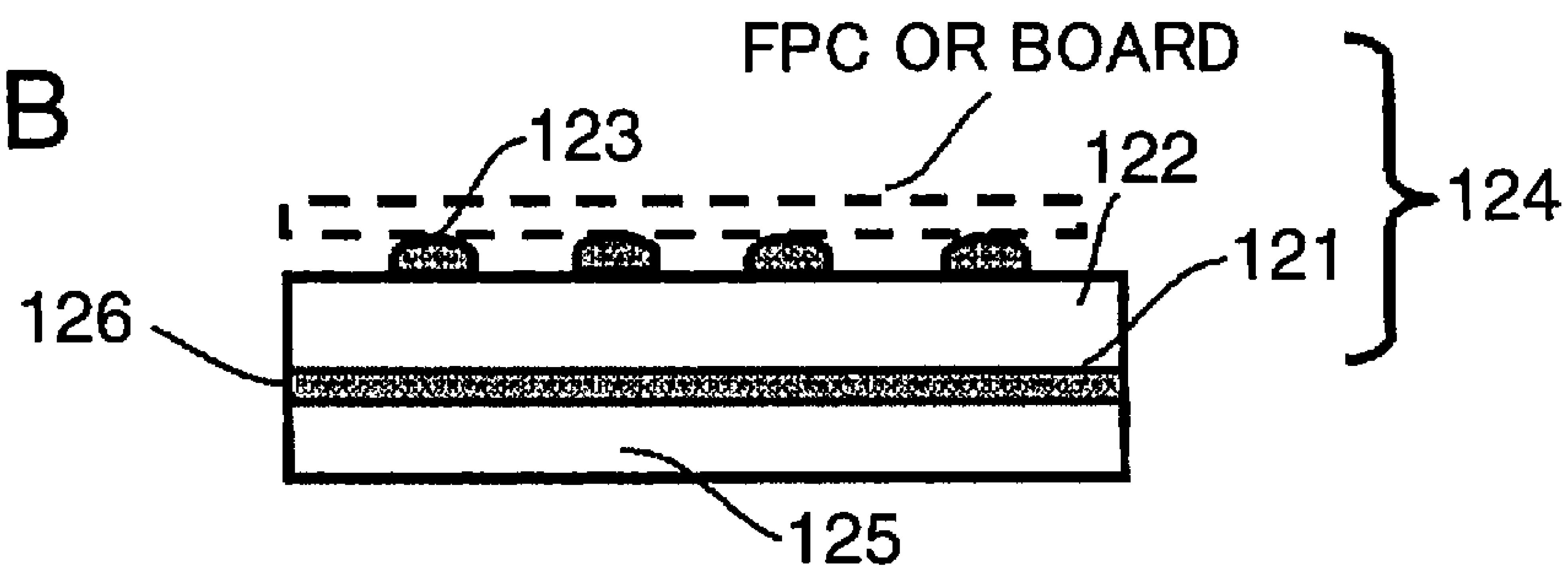



FIG.2C

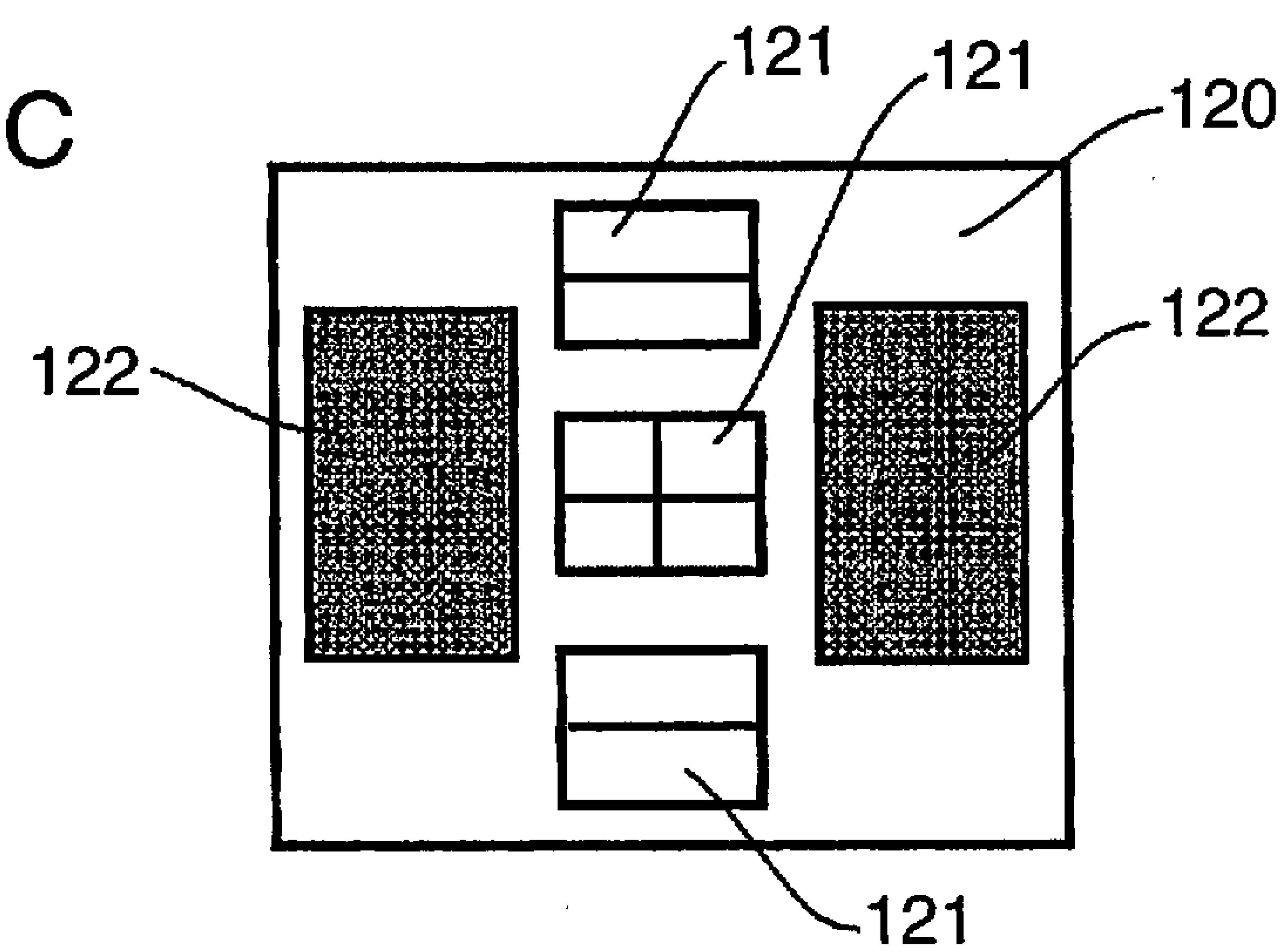


FIG.3

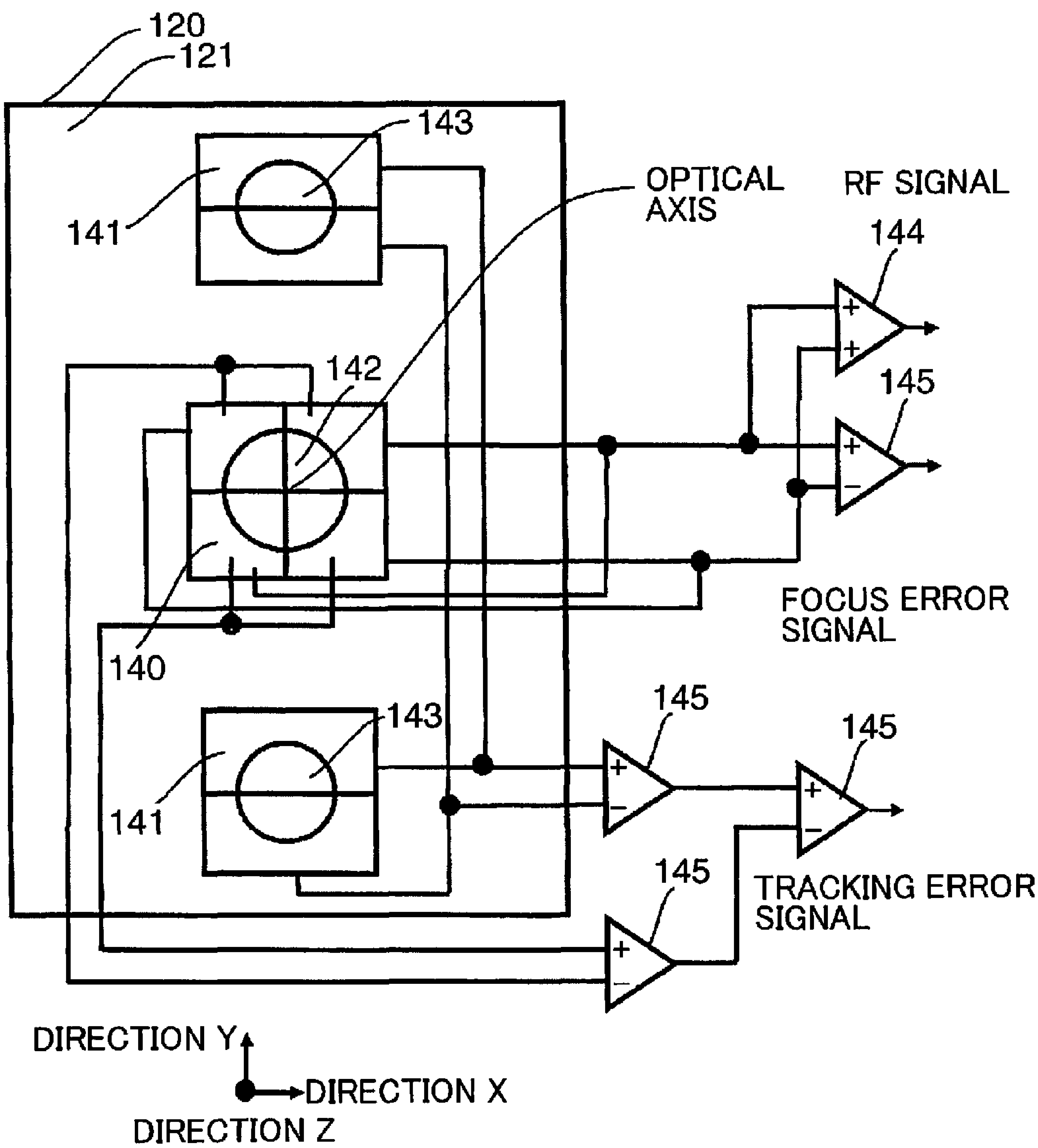

120
121
143
141
OPTICAL AXIS
RF SIGNAL
144
142
145
140
FOCUS ERROR SIGNAL
143
145
145
141
145
TRACKING ERROR SIGNAL
DIRECTION Y
DIRECTION X
DIRECTION Z

FIG.4A

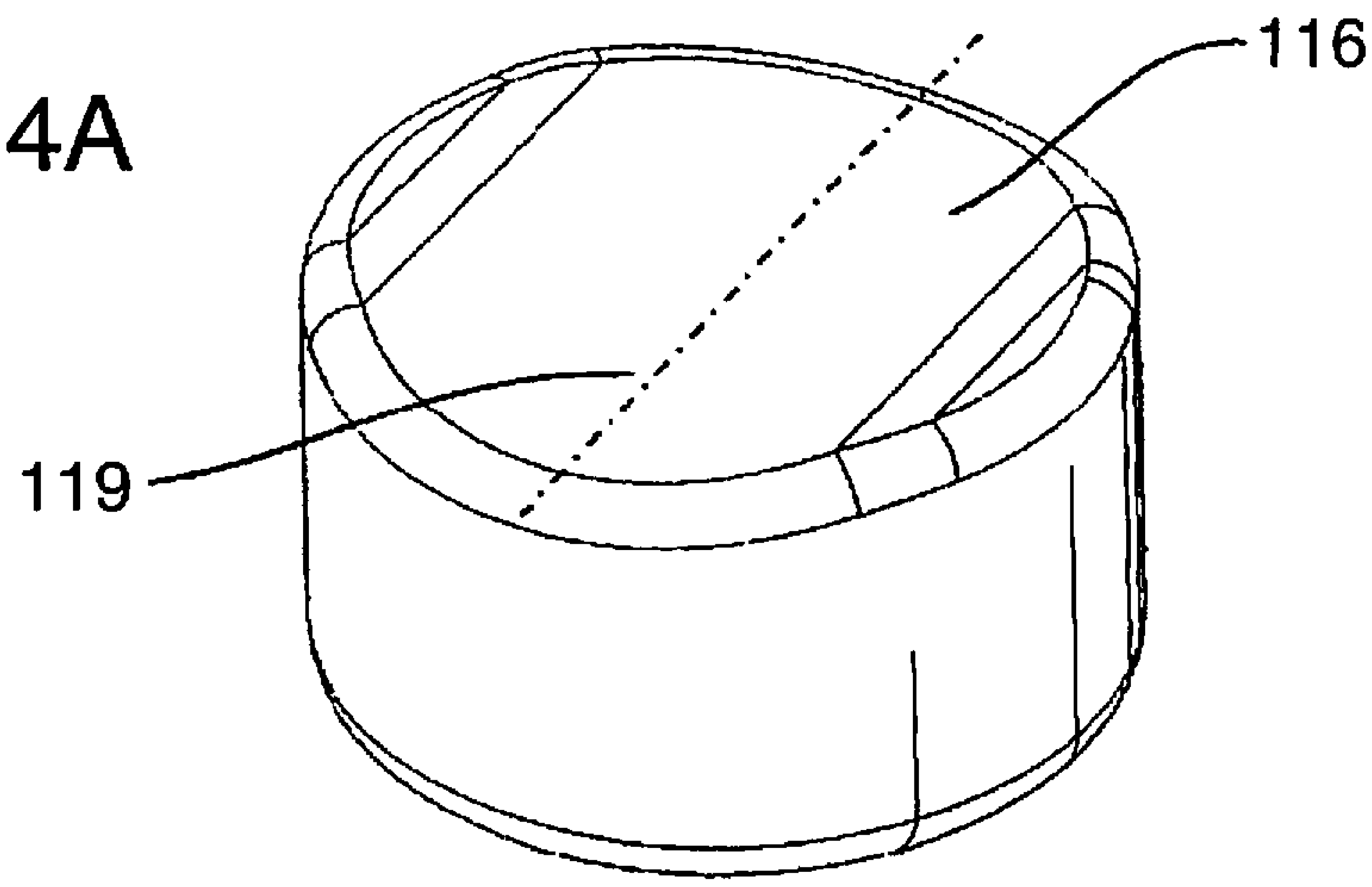



FIG.4B

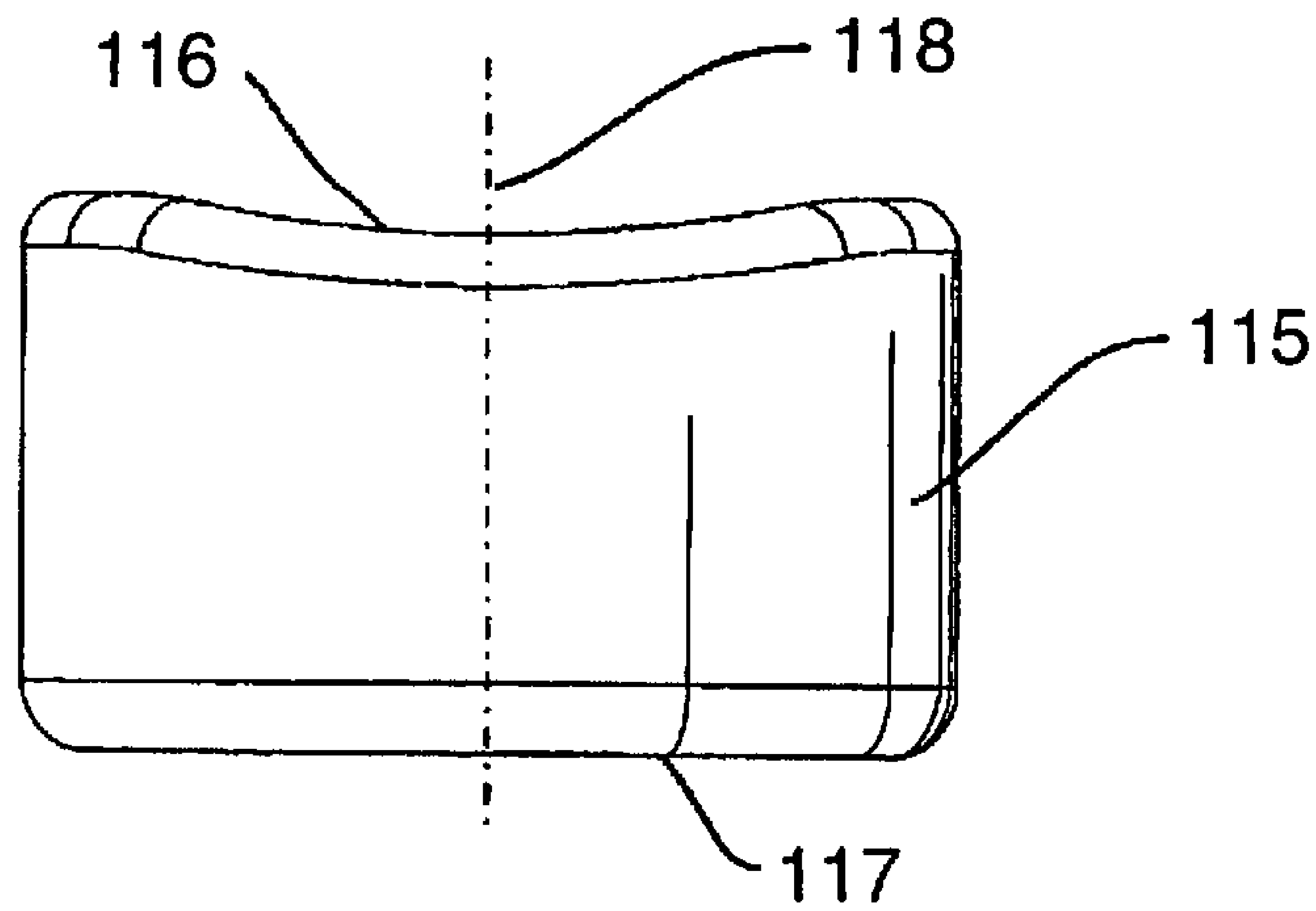



FIG.4C

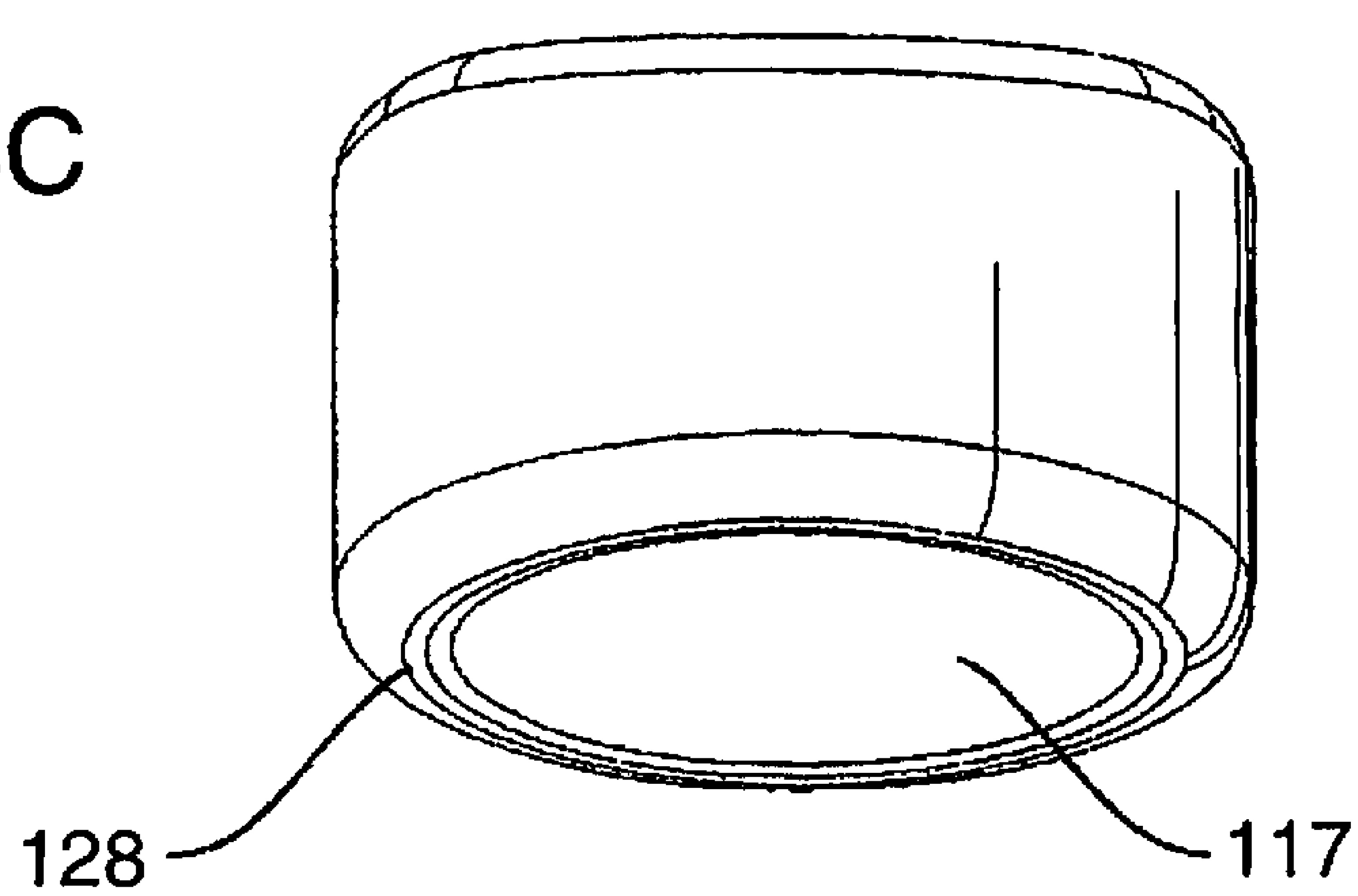


FIG.5

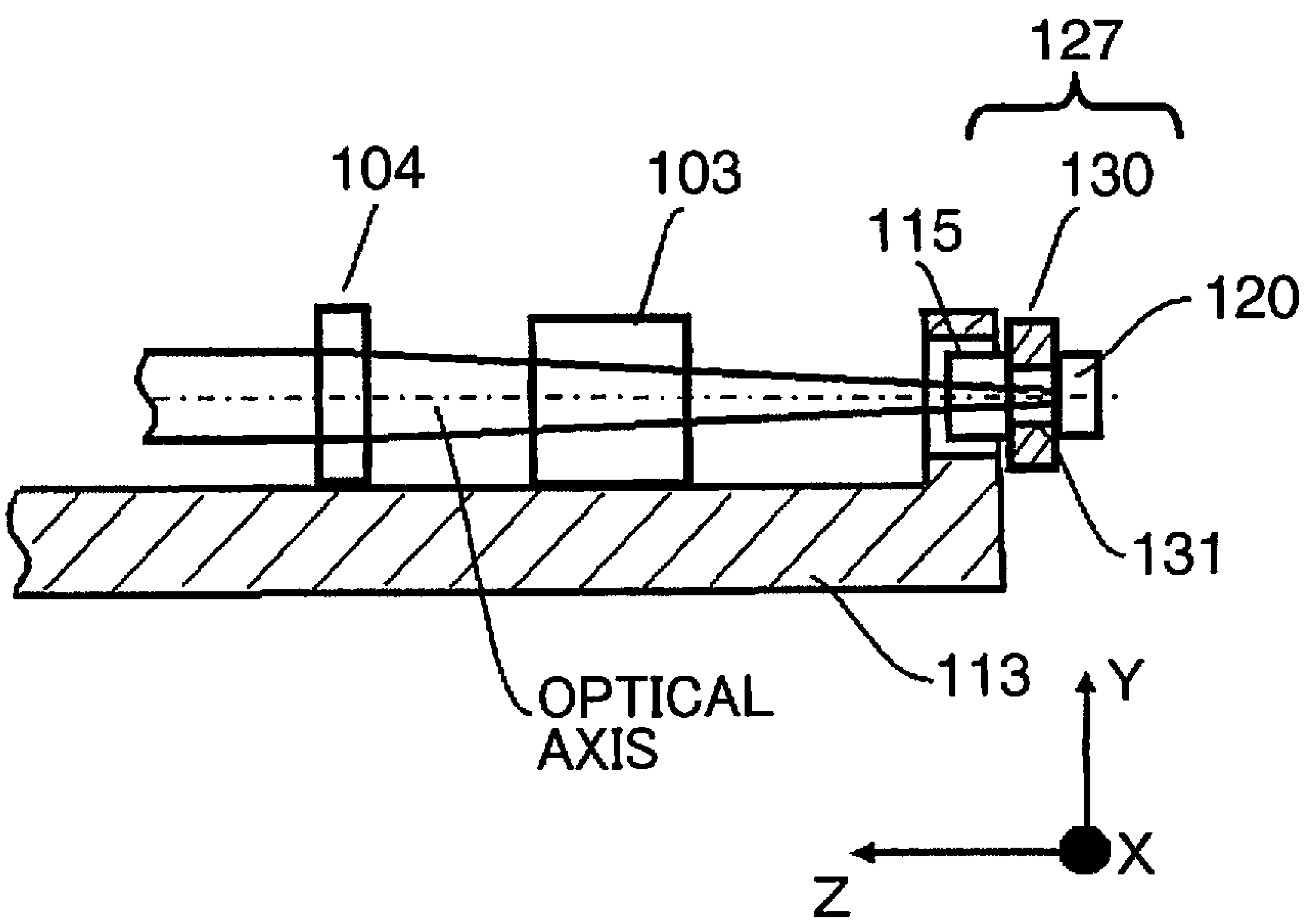


FIG.6A

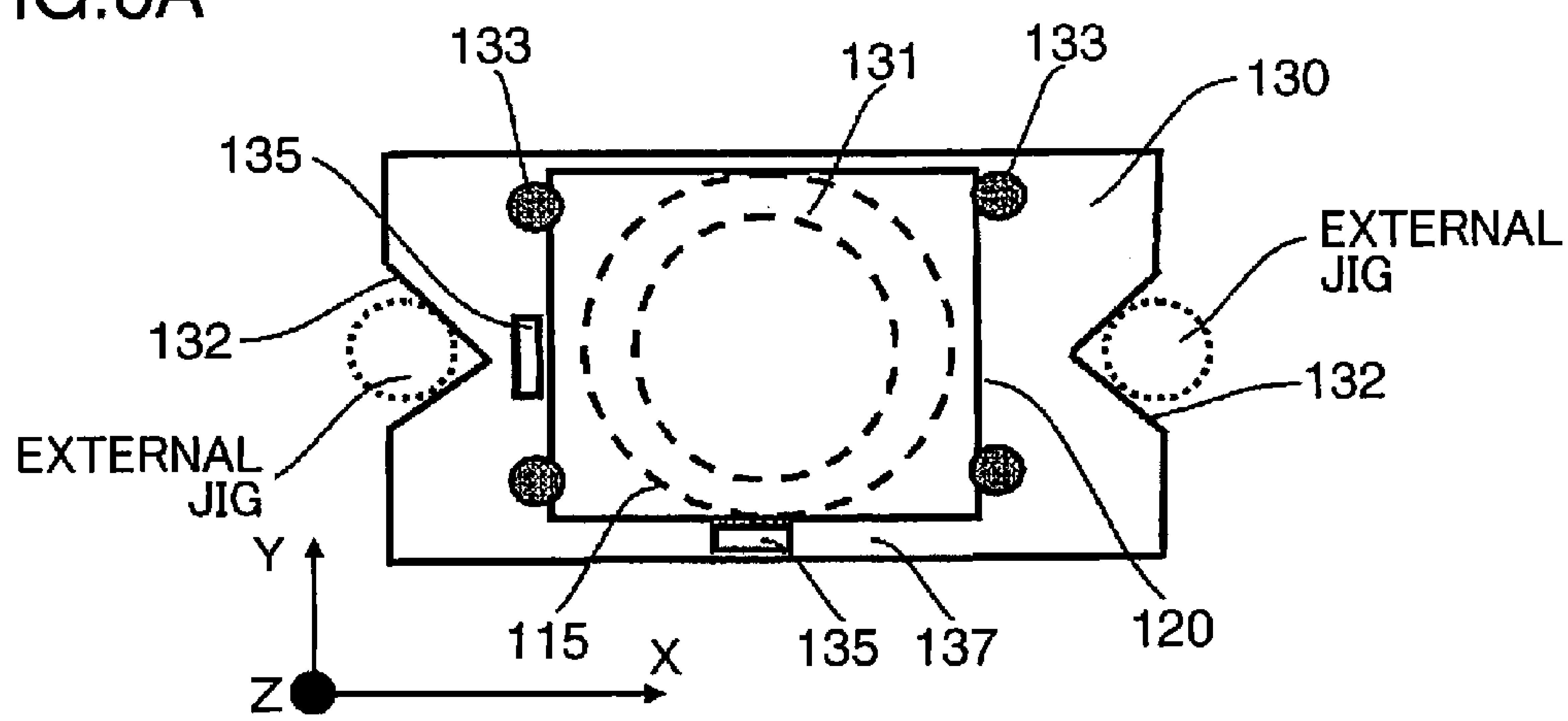



FIG.6B

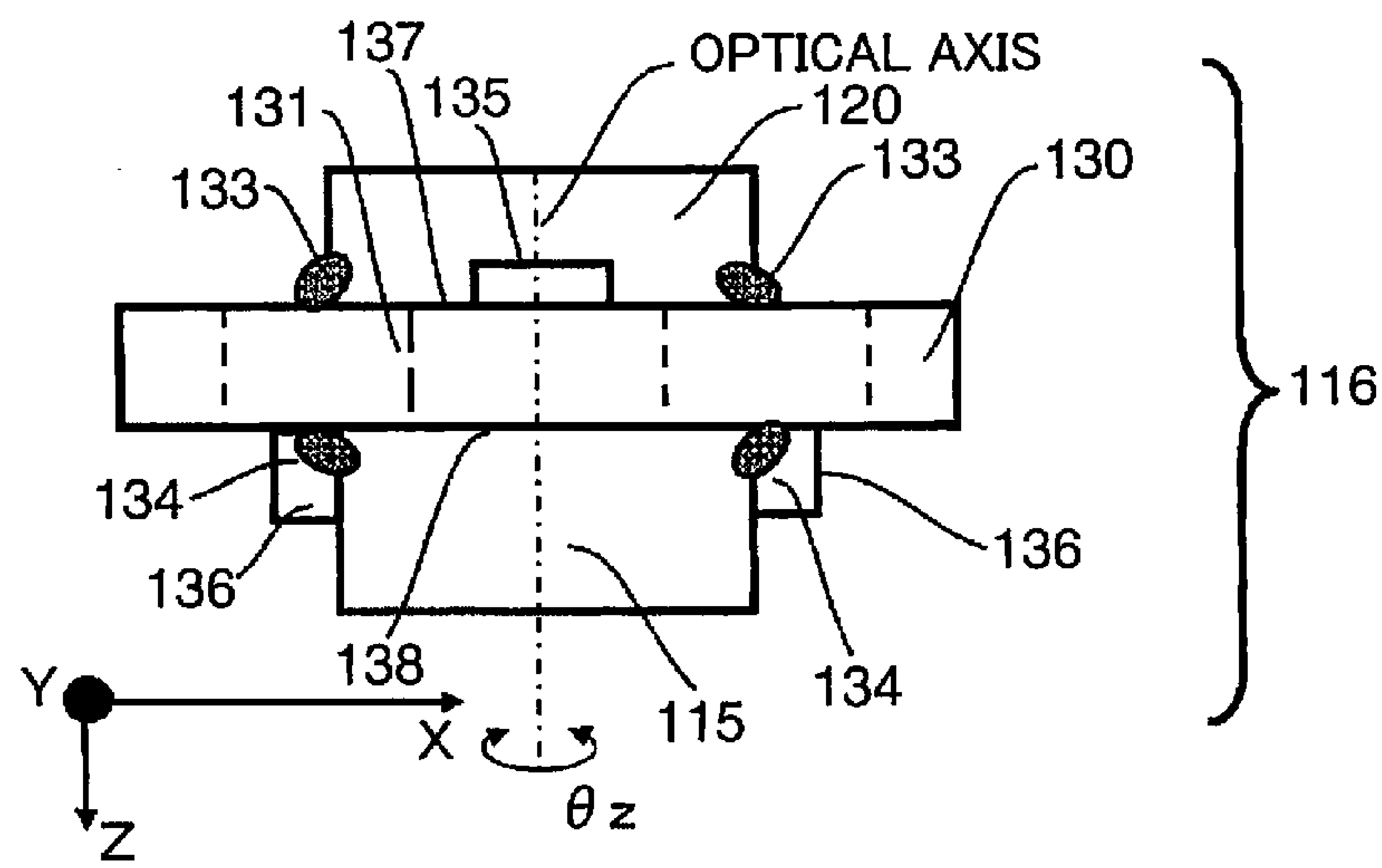



FIG.6C

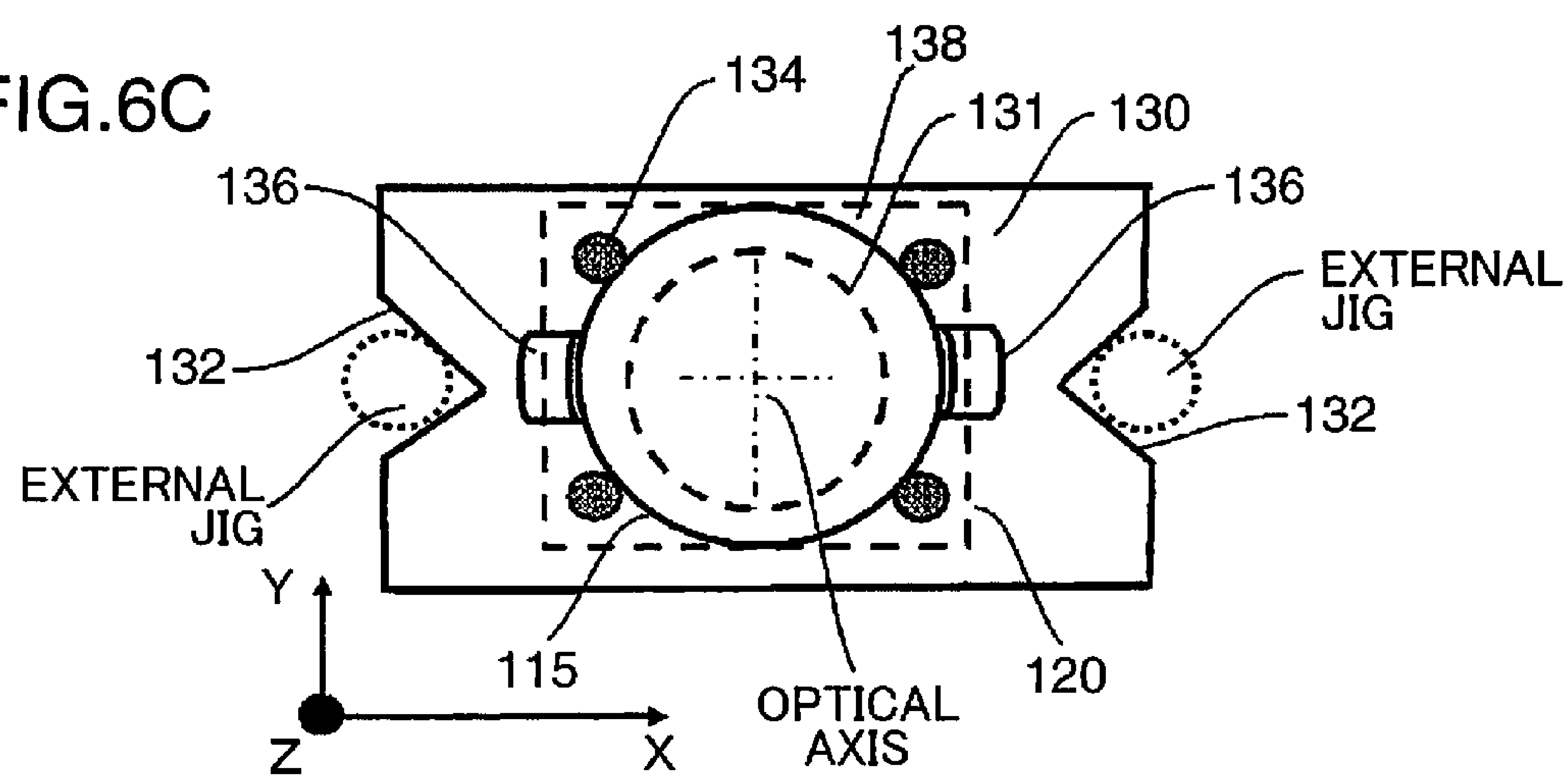


FIG.7

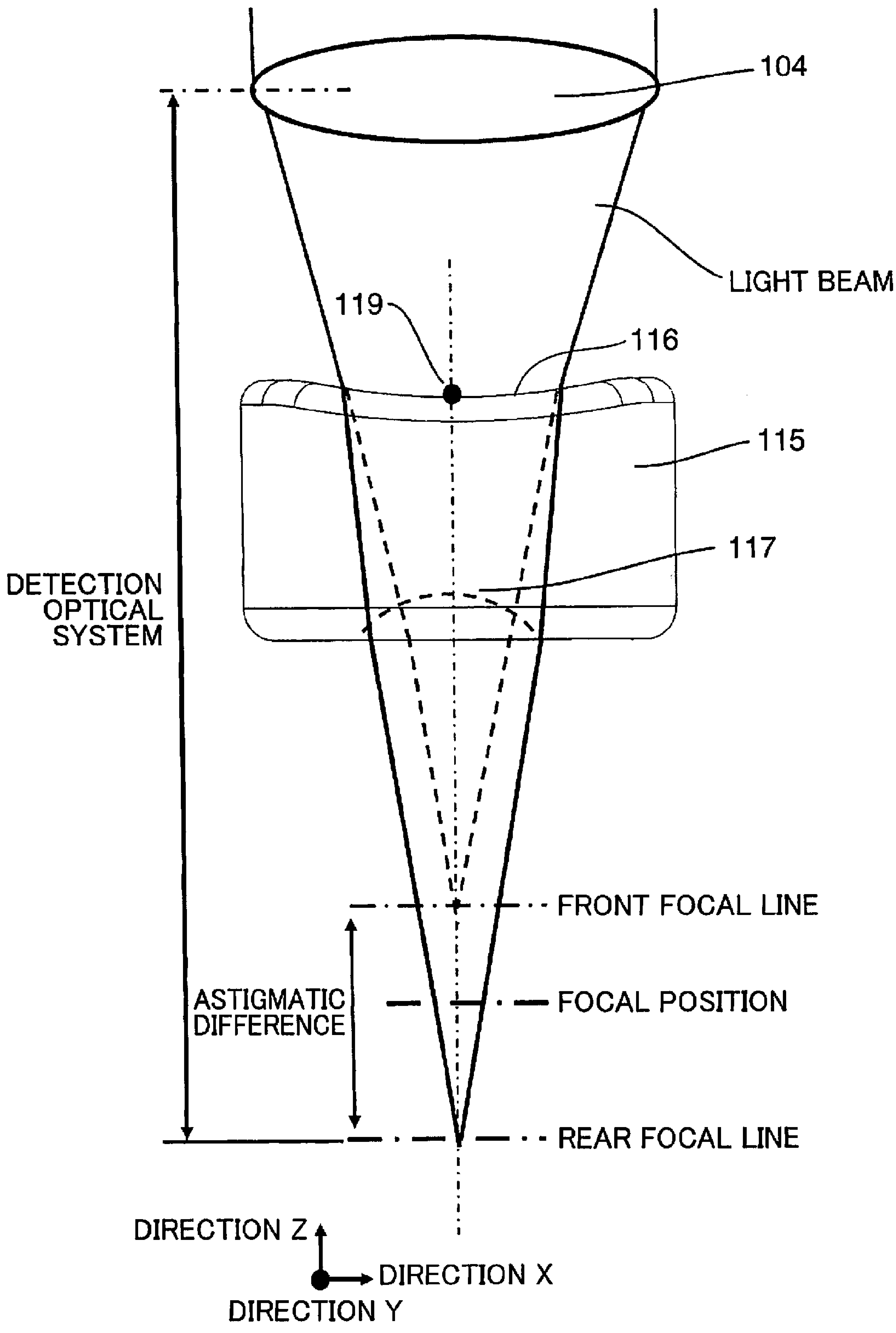

104
LIGHT BEAM
119
116
115
117
DETECTION OPTICAL SYSTEM
FRONT FOCAL LINE
ASTIGMATIC DIFFERENCE
FOCAL POSITION
REAR FOCAL LINE
DIRECTION Z
DIRECTION X
DIRECTION Y

FIG.8

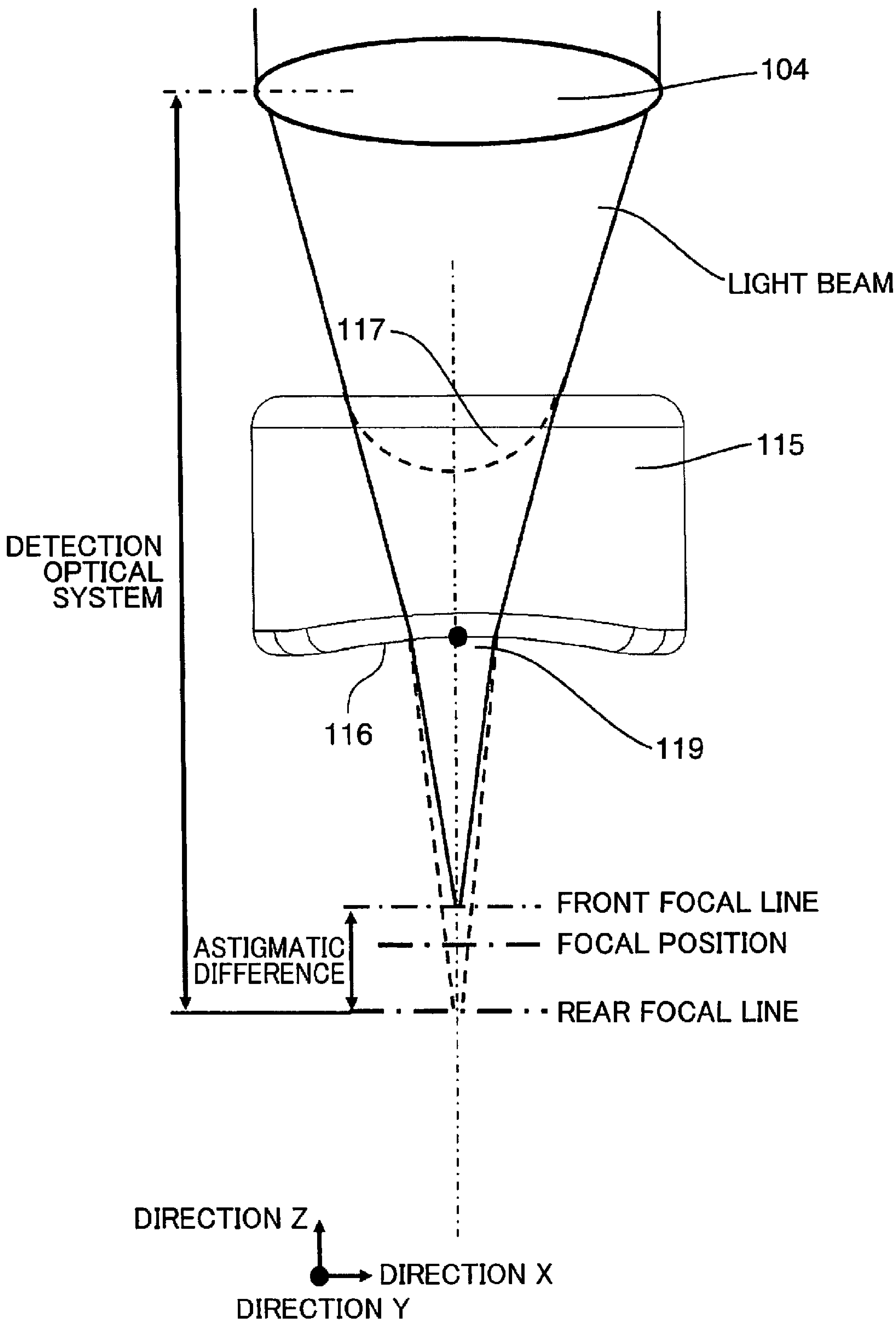

104
LIGHT BEAM
117
115
DETECTION OPTICAL SYSTEM
116
119
FRONT FOCAL LINE
ASTIGMATIC DIFFERENCE
FOCAL POSITION
REAR FOCAL LINE
DIRECTION Z
DIRECTION X
DIRECTION Y

FIG.9A

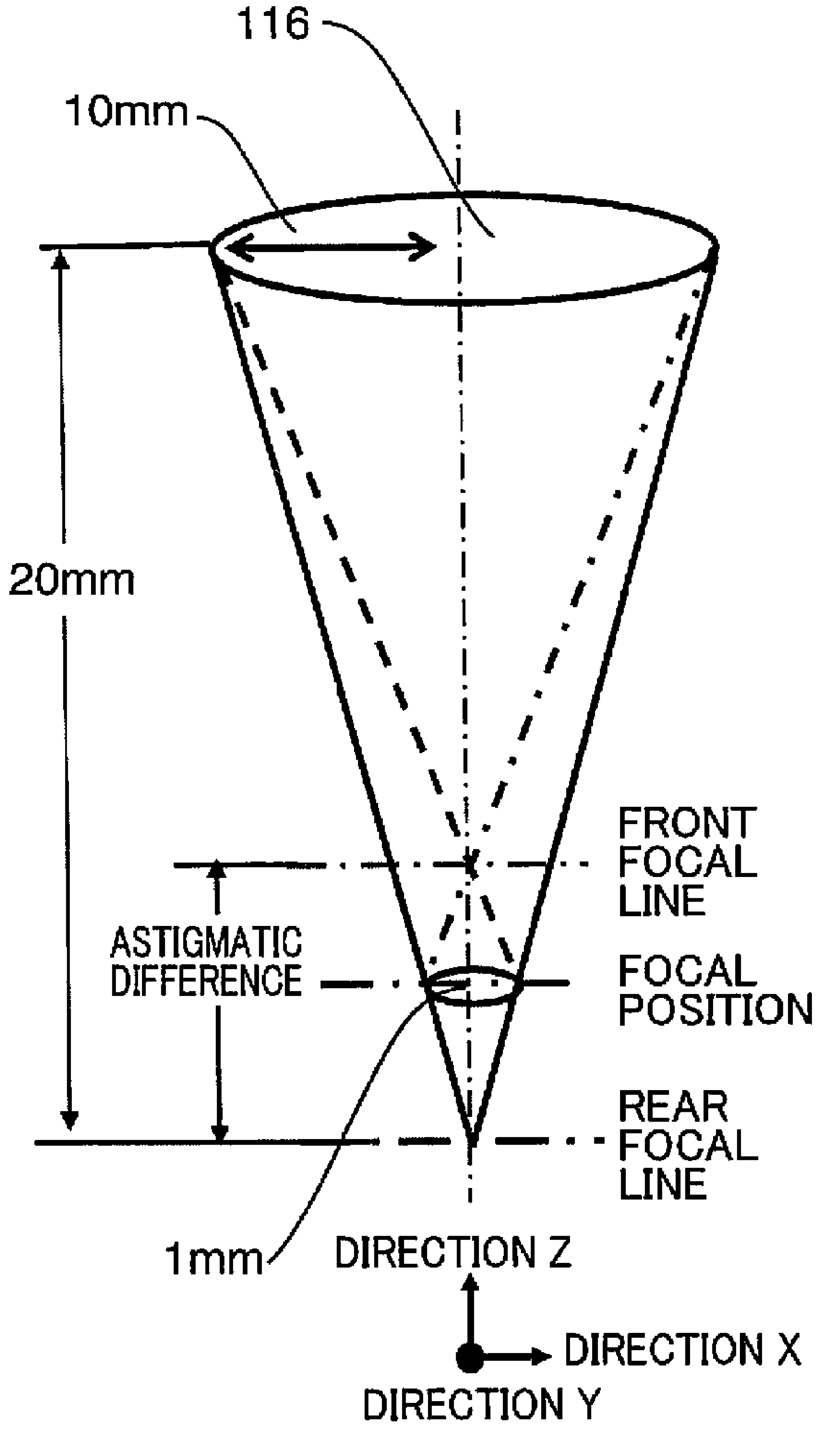



FIG.9B

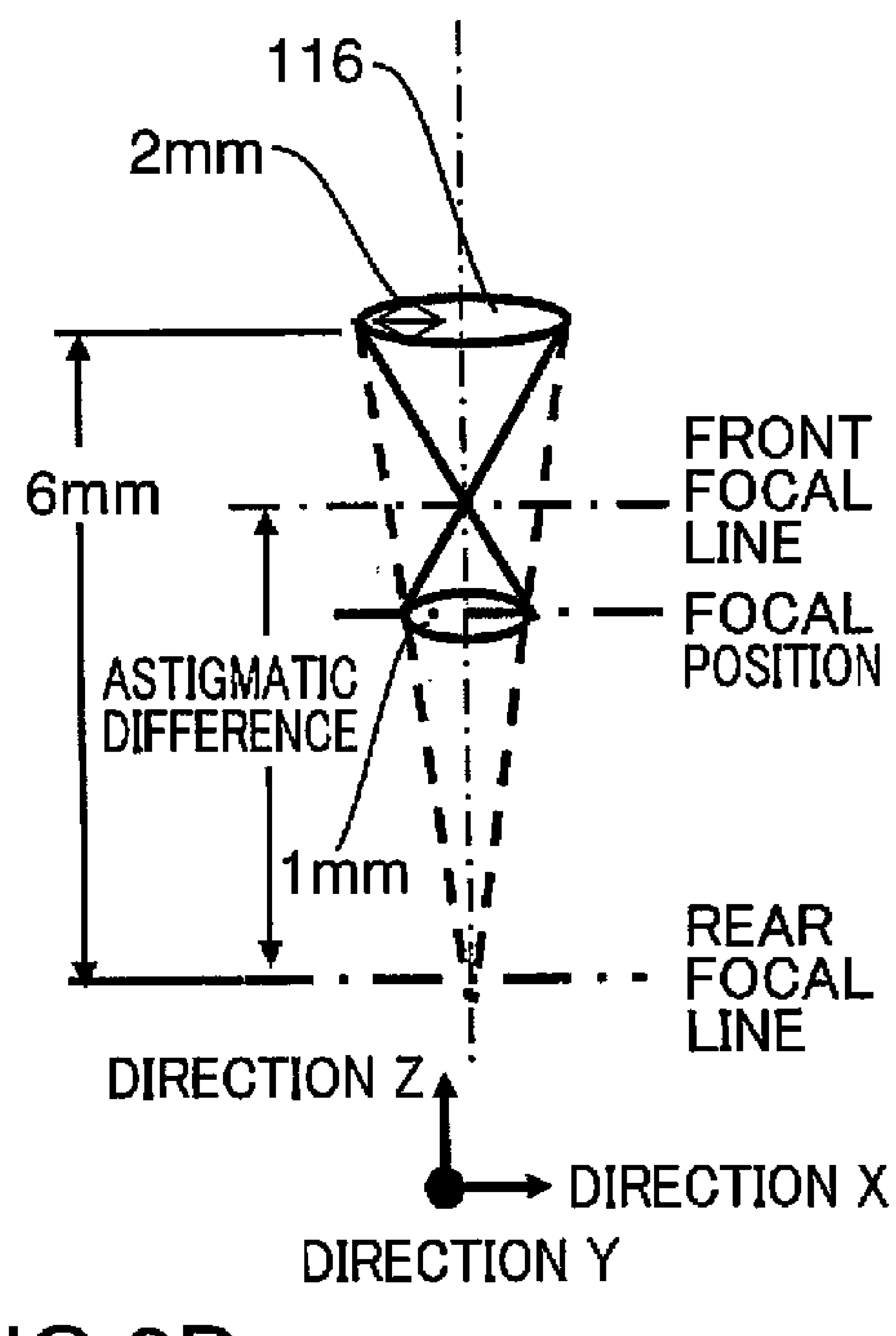



FIG.9C

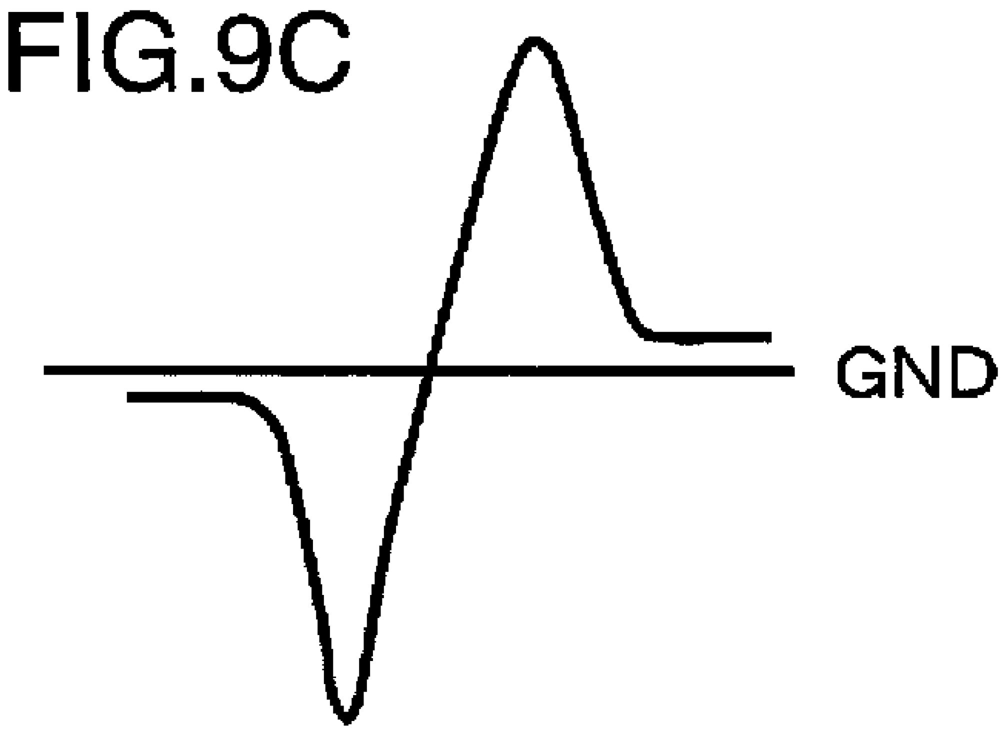



FIG.9D

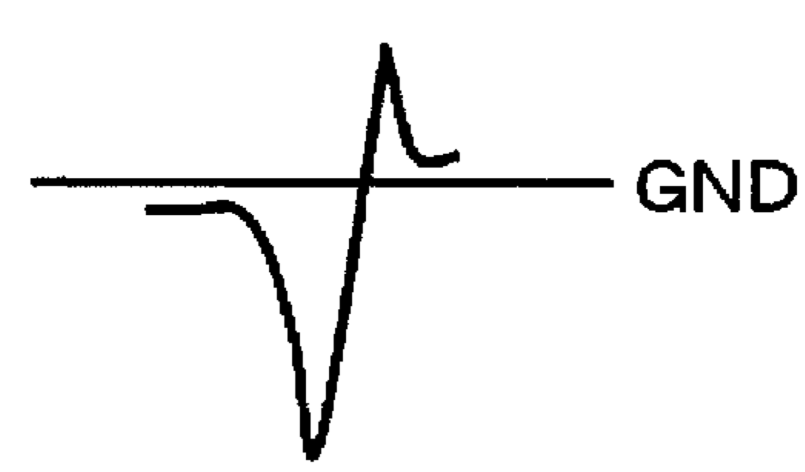


FIG.10

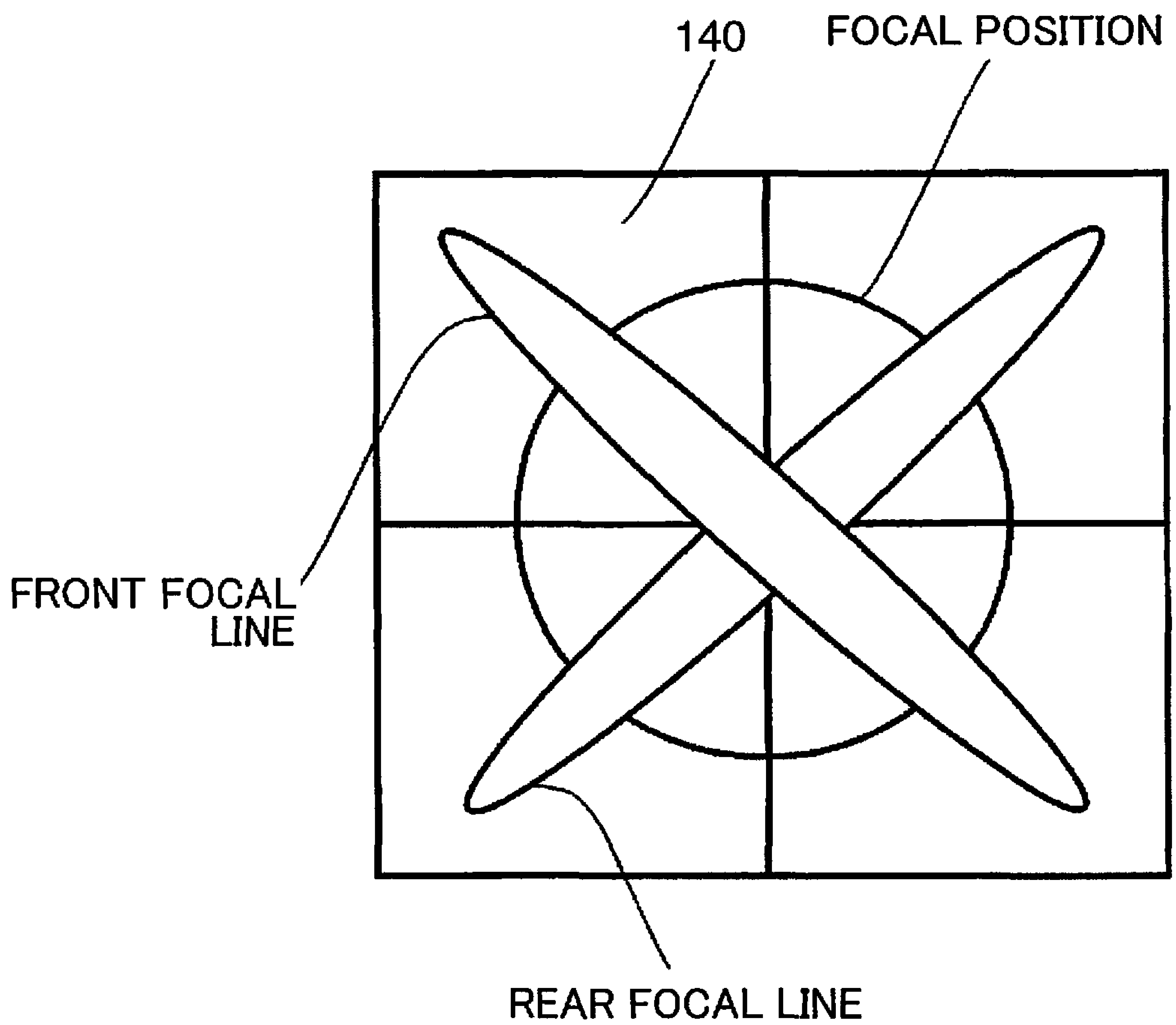


FIG.11

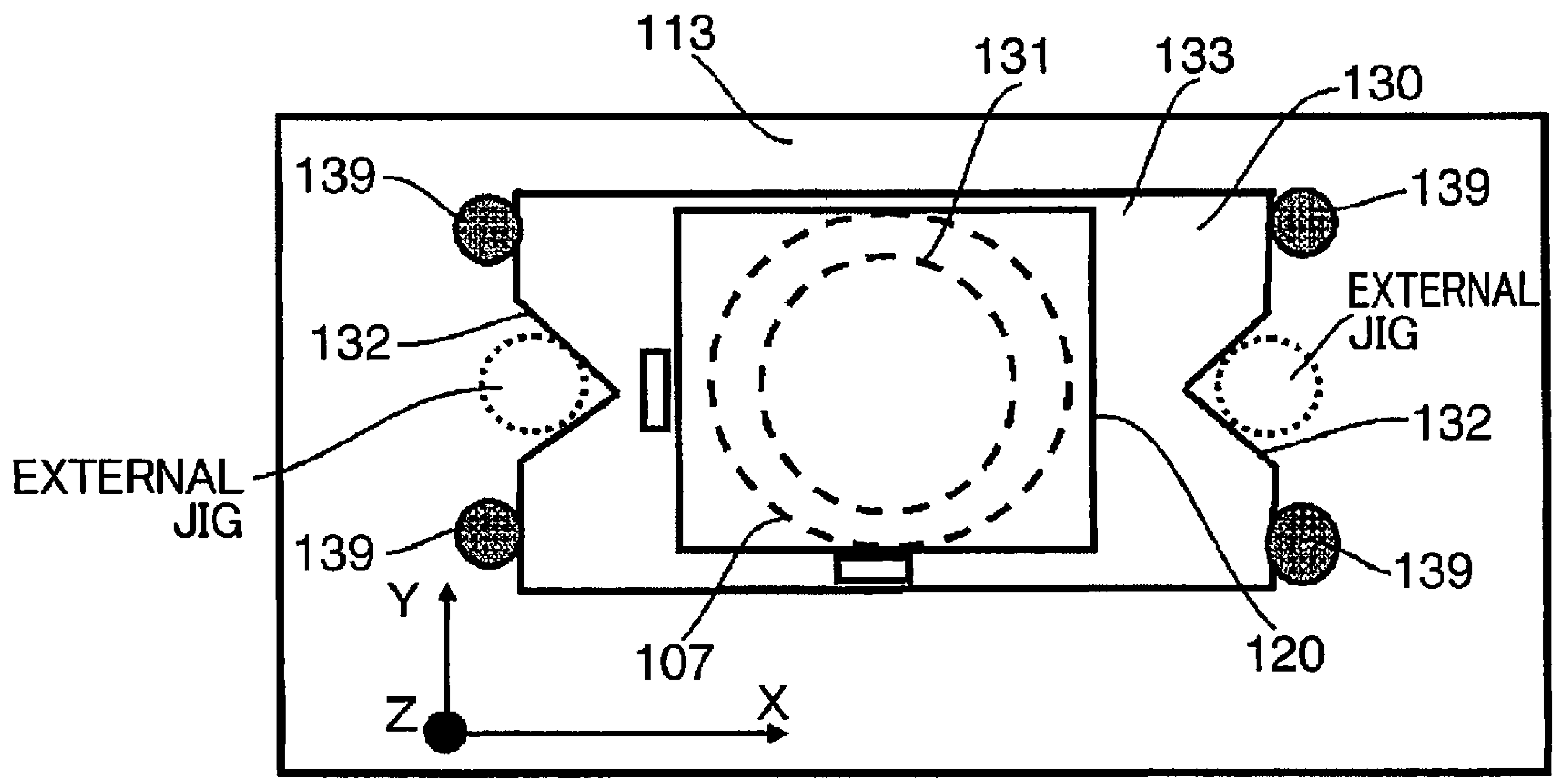
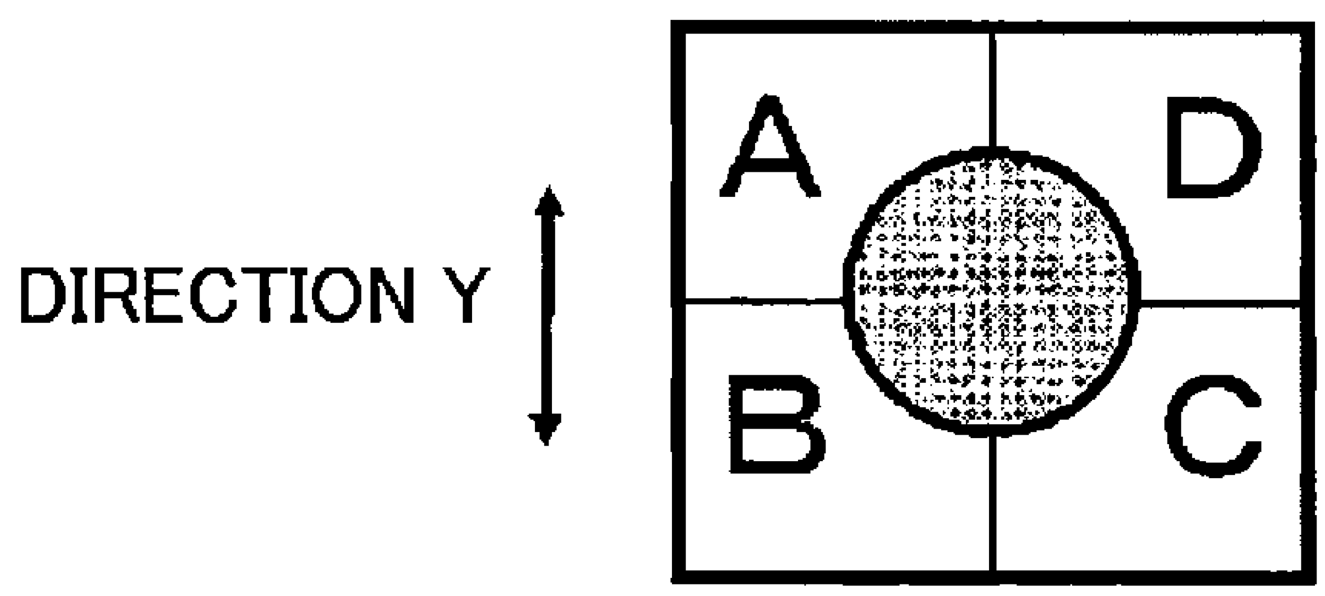

113
131
133
130
139
139
EXTERNAL
JIG
132
132
EXTERNAL
JIG
139
139
Y
Z
X
107
120

FIG.12A

| | MAGNIFICATION OF THE DETECTION OPTICAL SYSTEM (LATERAL MAGNIFICATION $\beta$) | | | |
|---|---|---|---|---|
| | 10 | 12 | 14 | 16 |
| CONCAVE LENS PORTION RADIUS (mm) | 12 | 4.4 | 2.6 | 1.9 |
| SPOT DIAMETER OFFSET ($\mu$m) | 1.2 | 2.1 | 3.1 | 4 |

FIG.12B




PD BALANCE DEFINITION (DIRECTION Y)

$$=((A+D)-(B+C))/(A+B+C+D)$$

FIG.13A

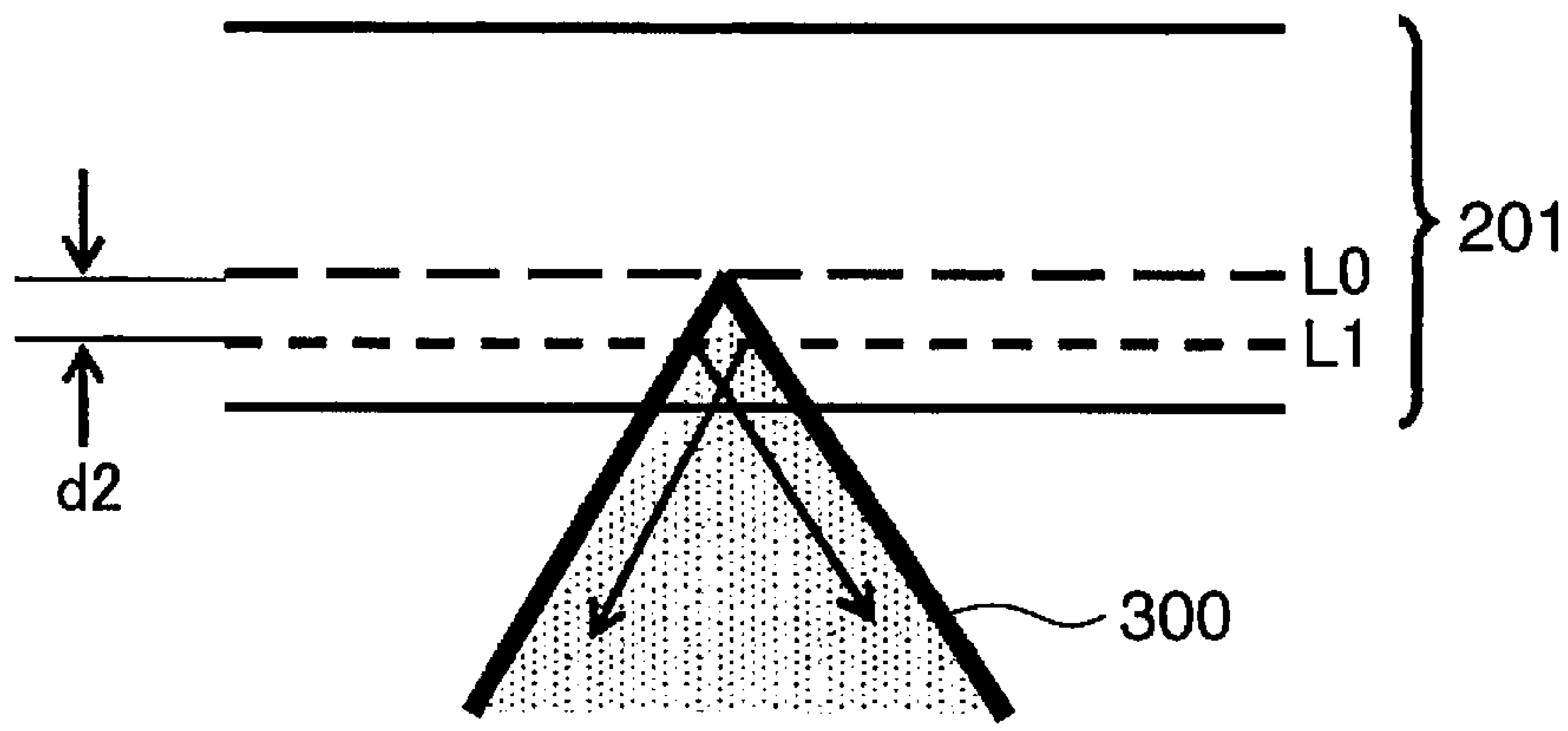



FIG.13B

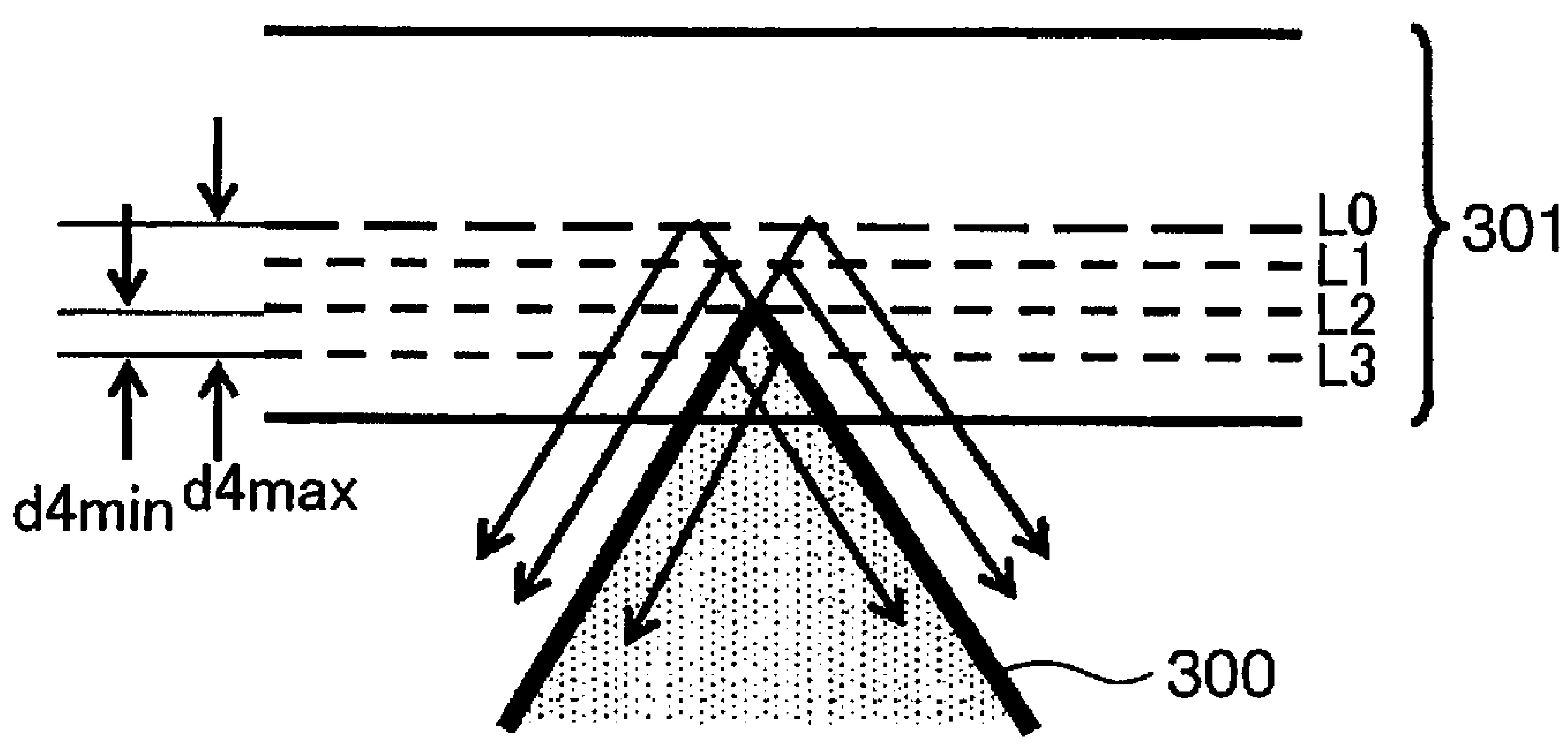


FIG.14A

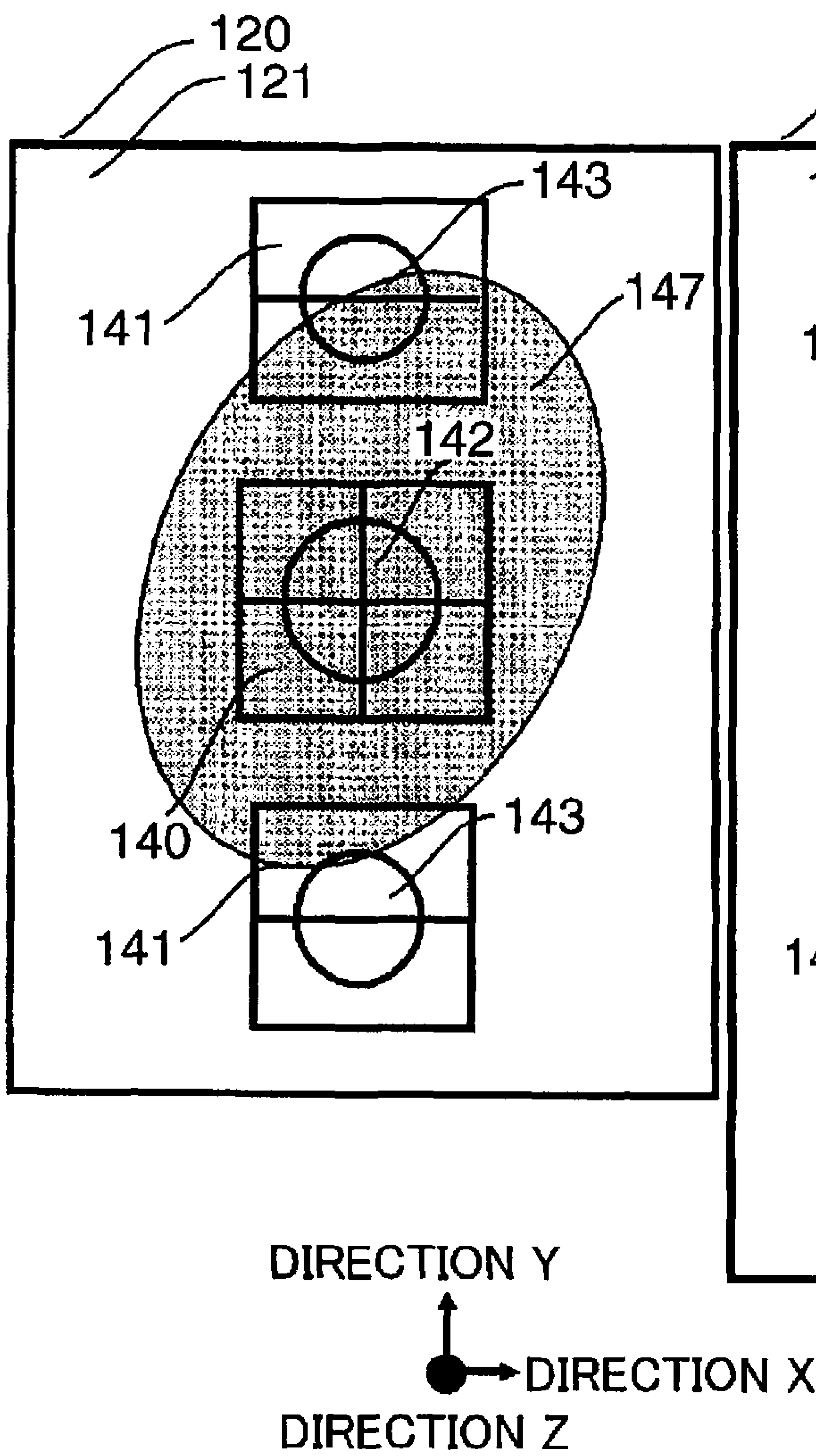



FIG.14B

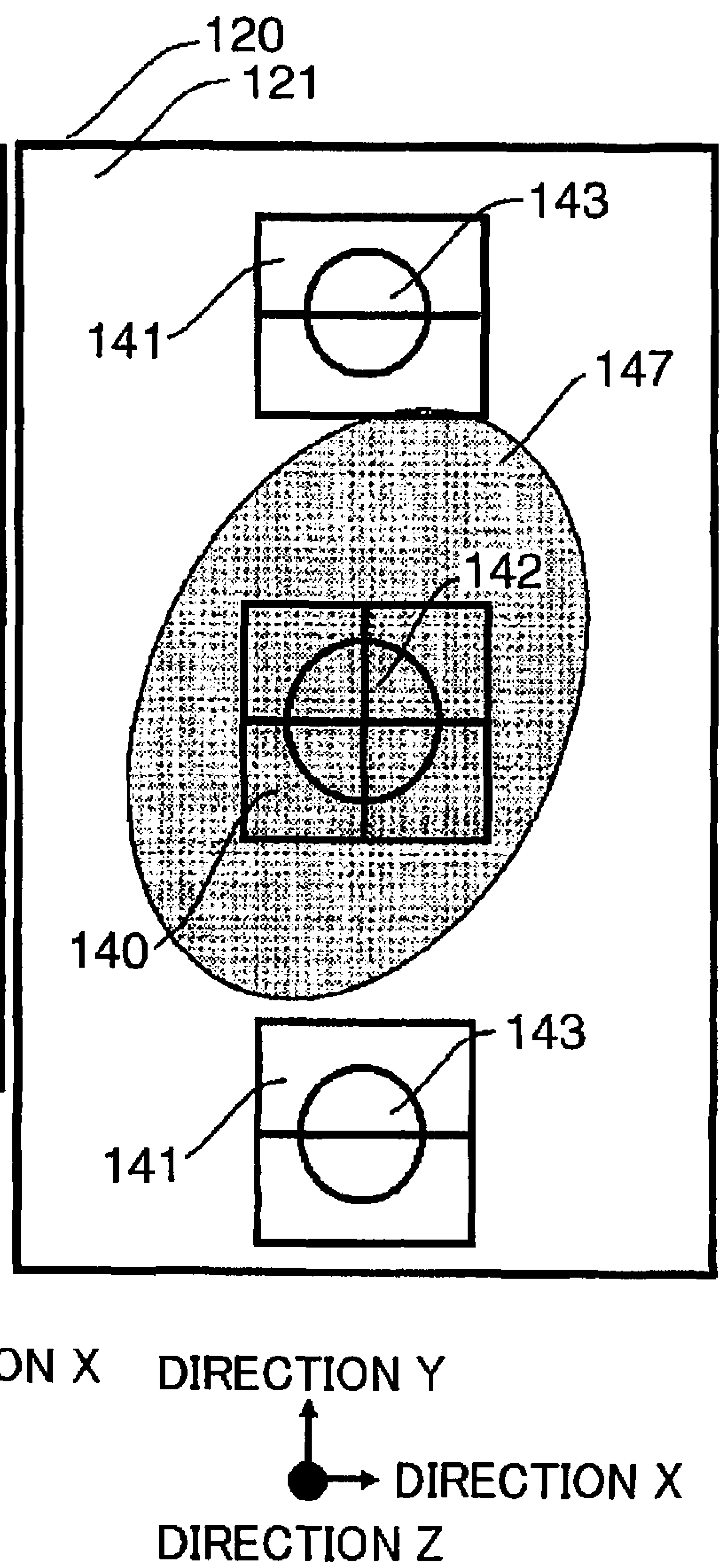


FIG.15A

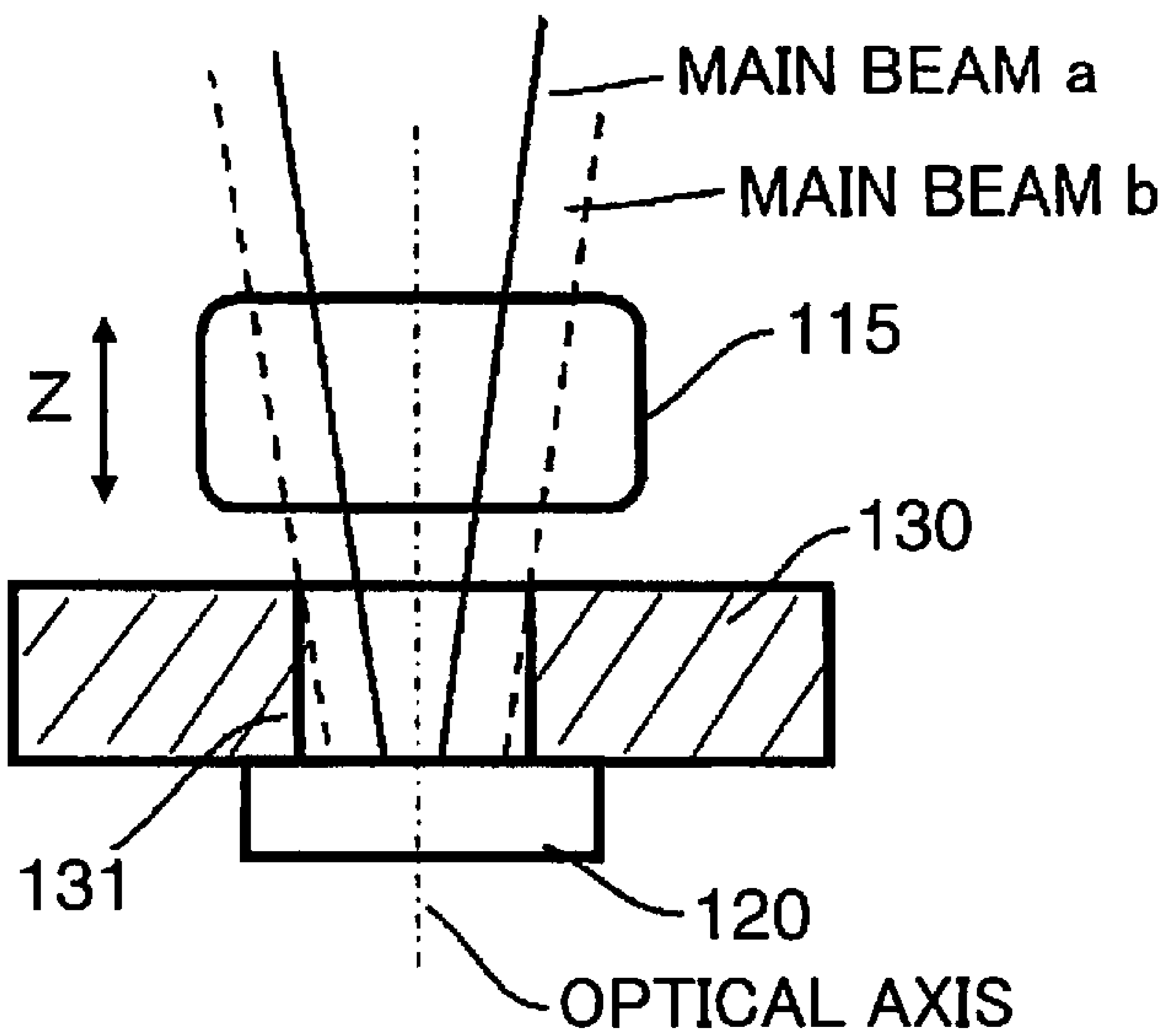



FIG.15B

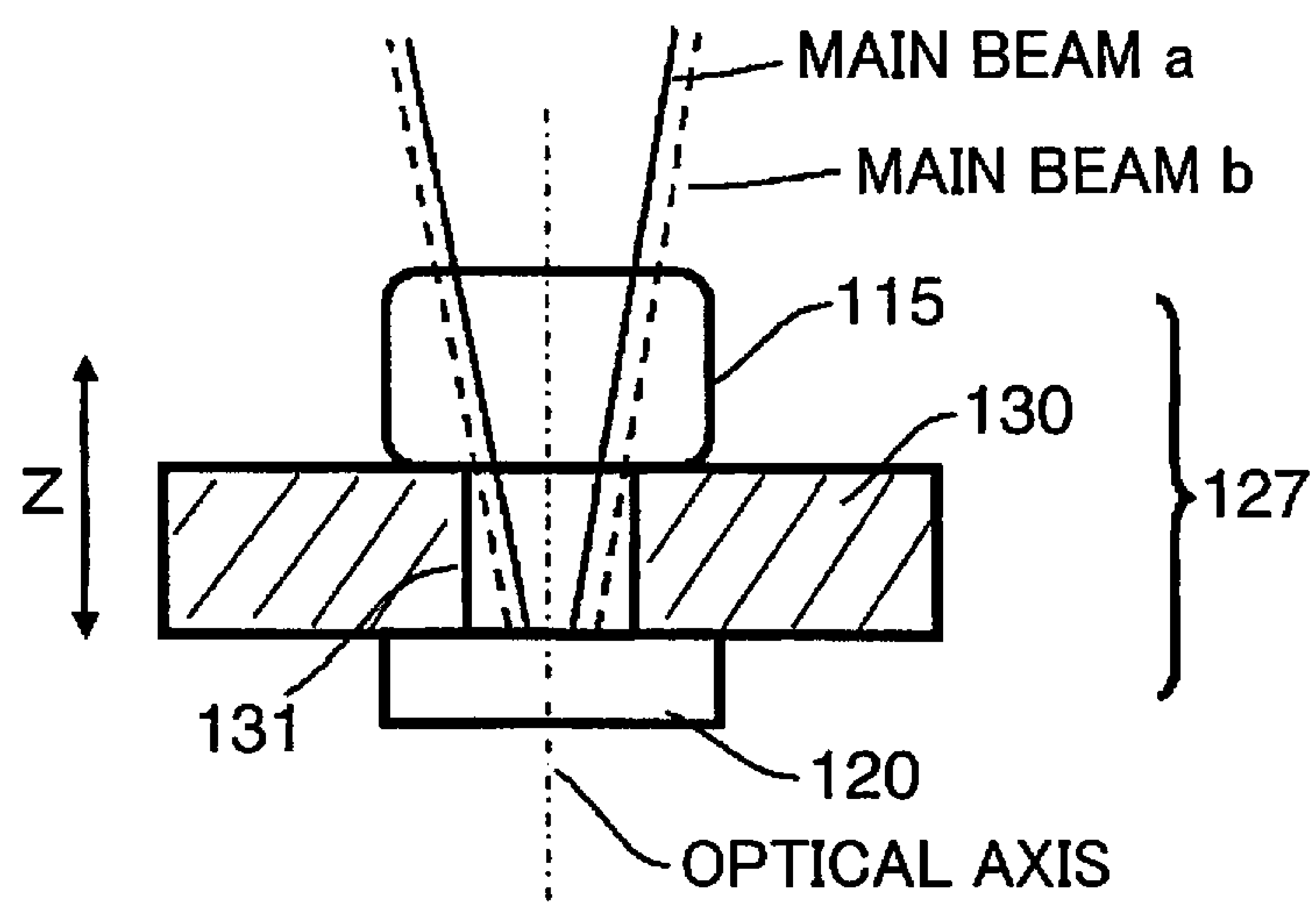


FIG.16A

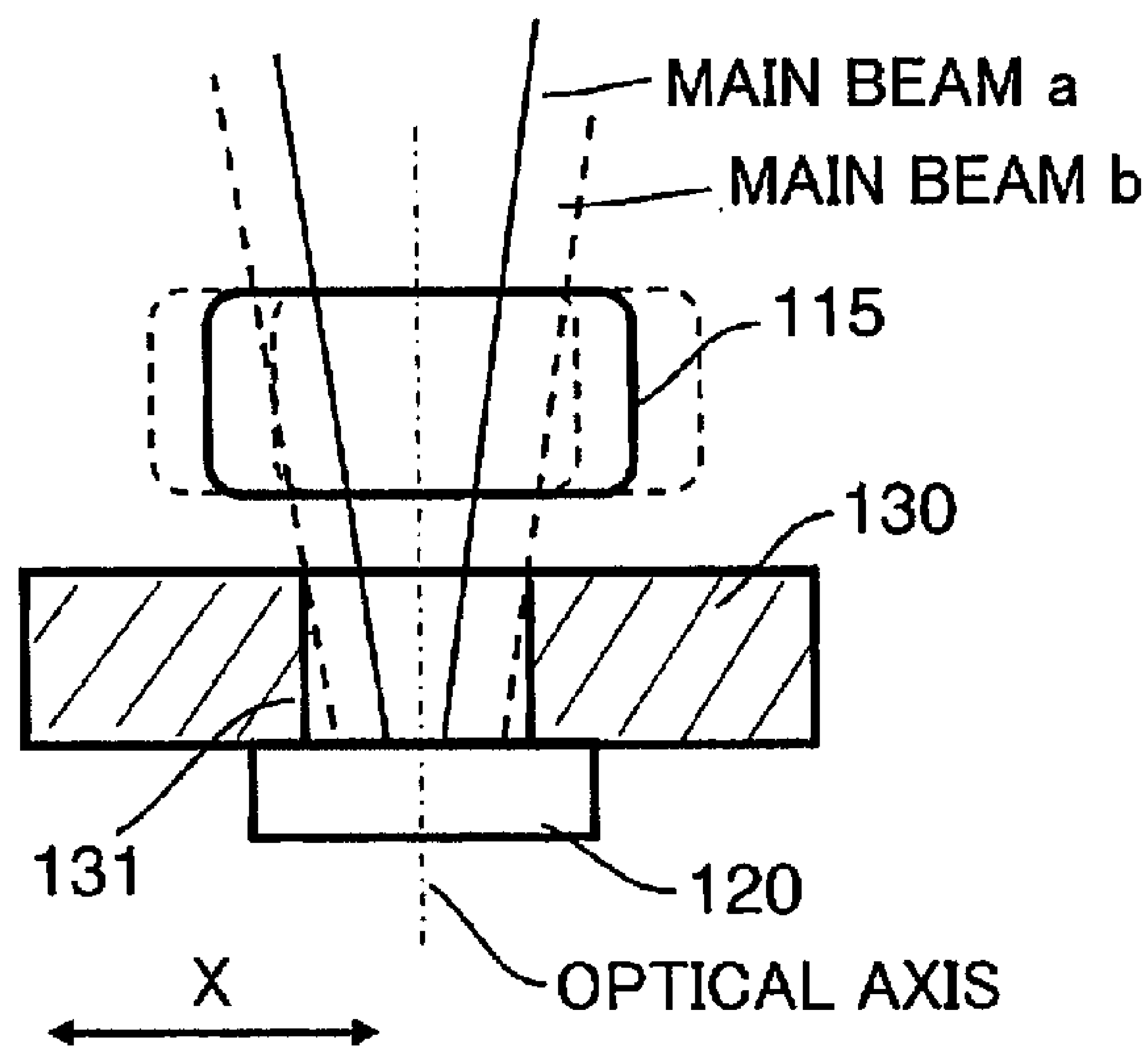



FIG.16B

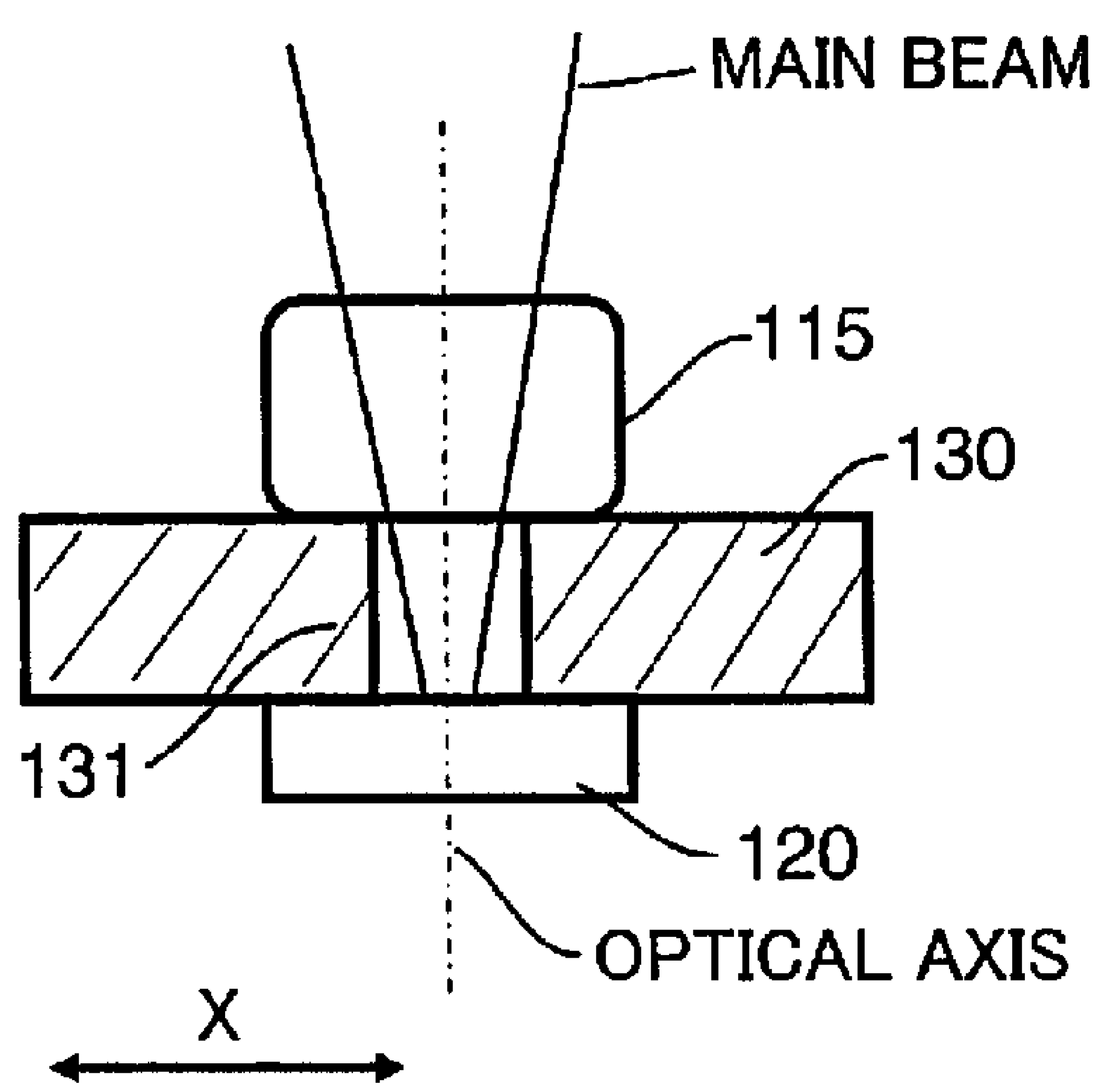



FIG.16C

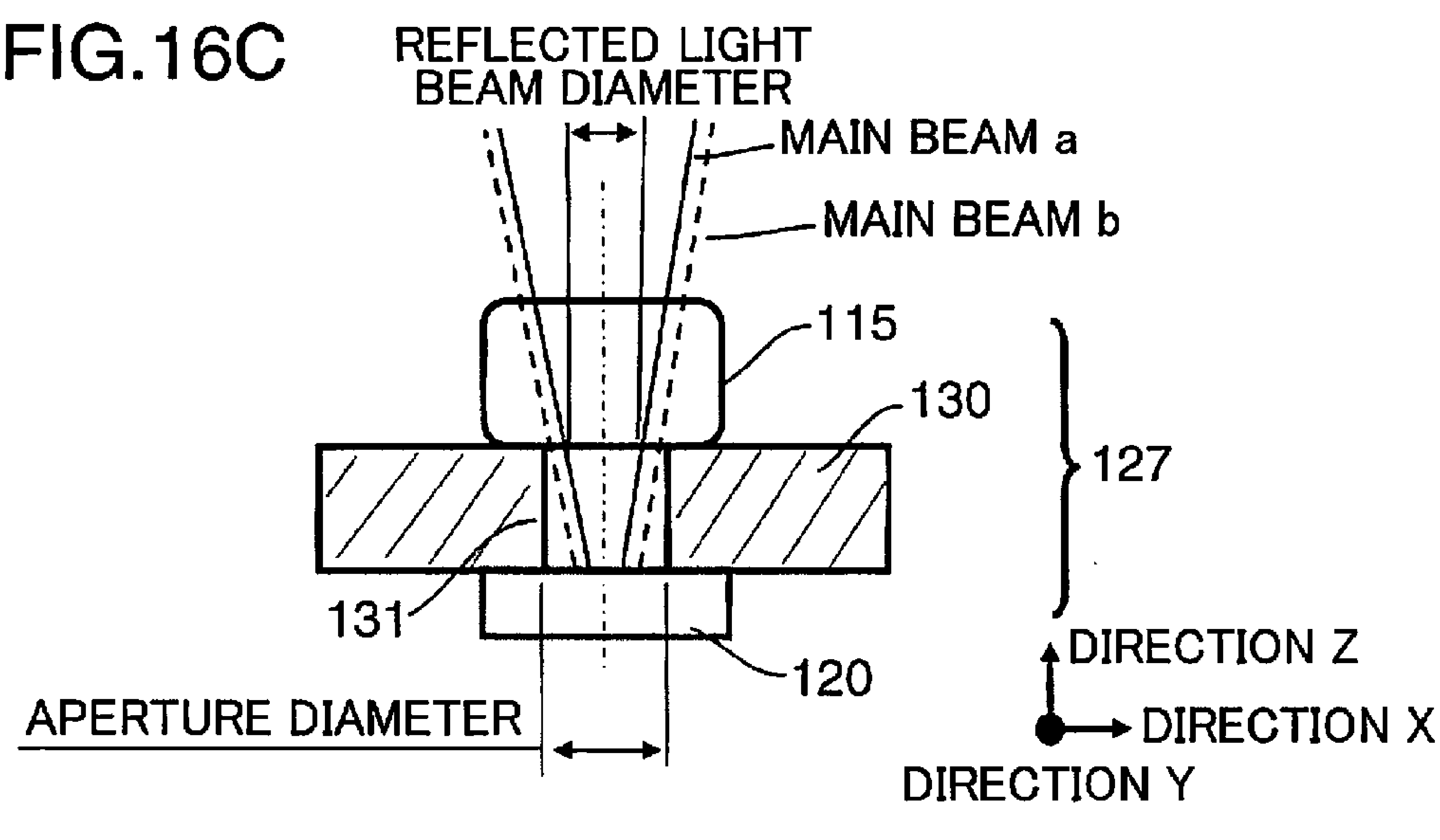


FIG.17

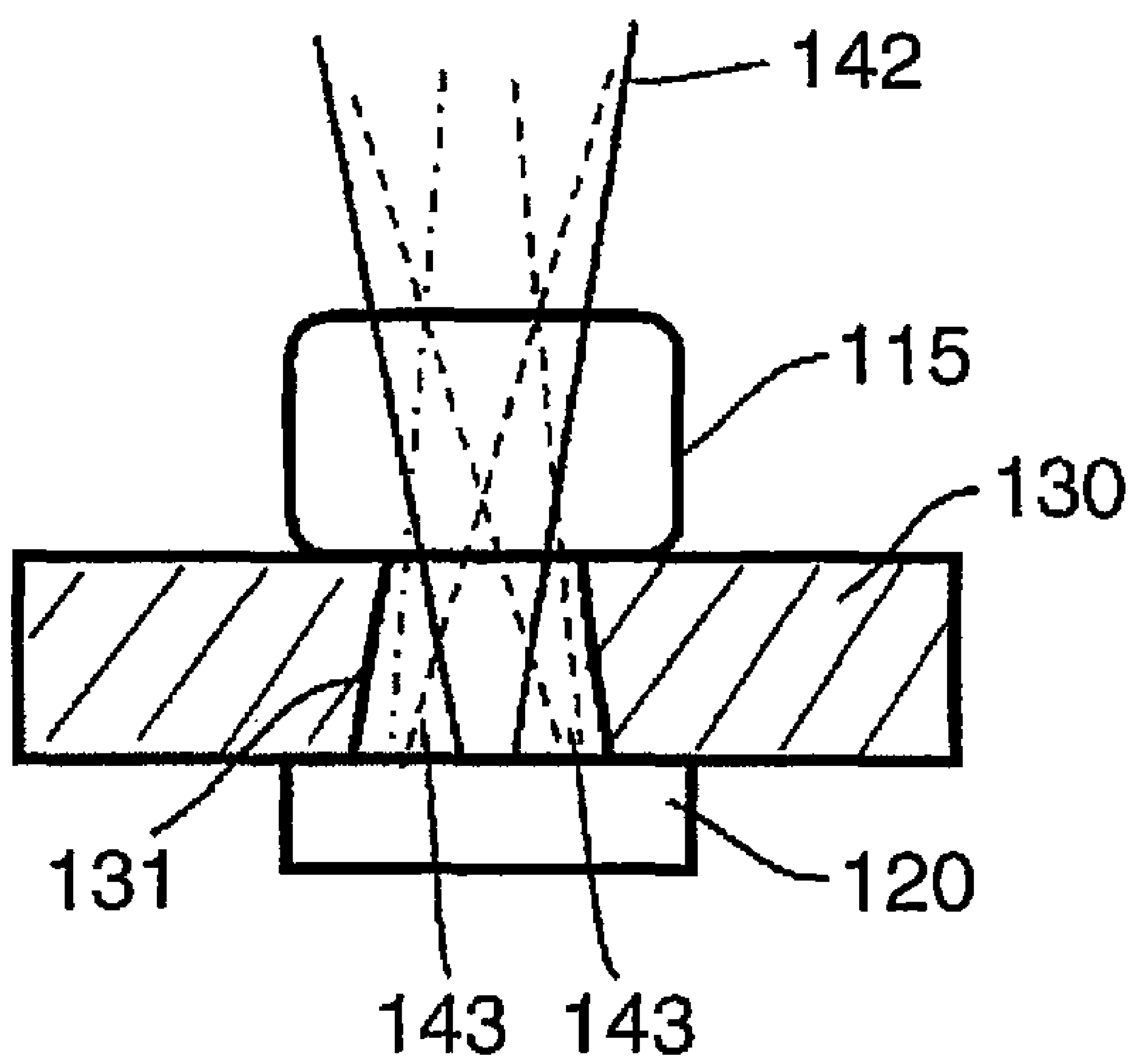


FIG.18

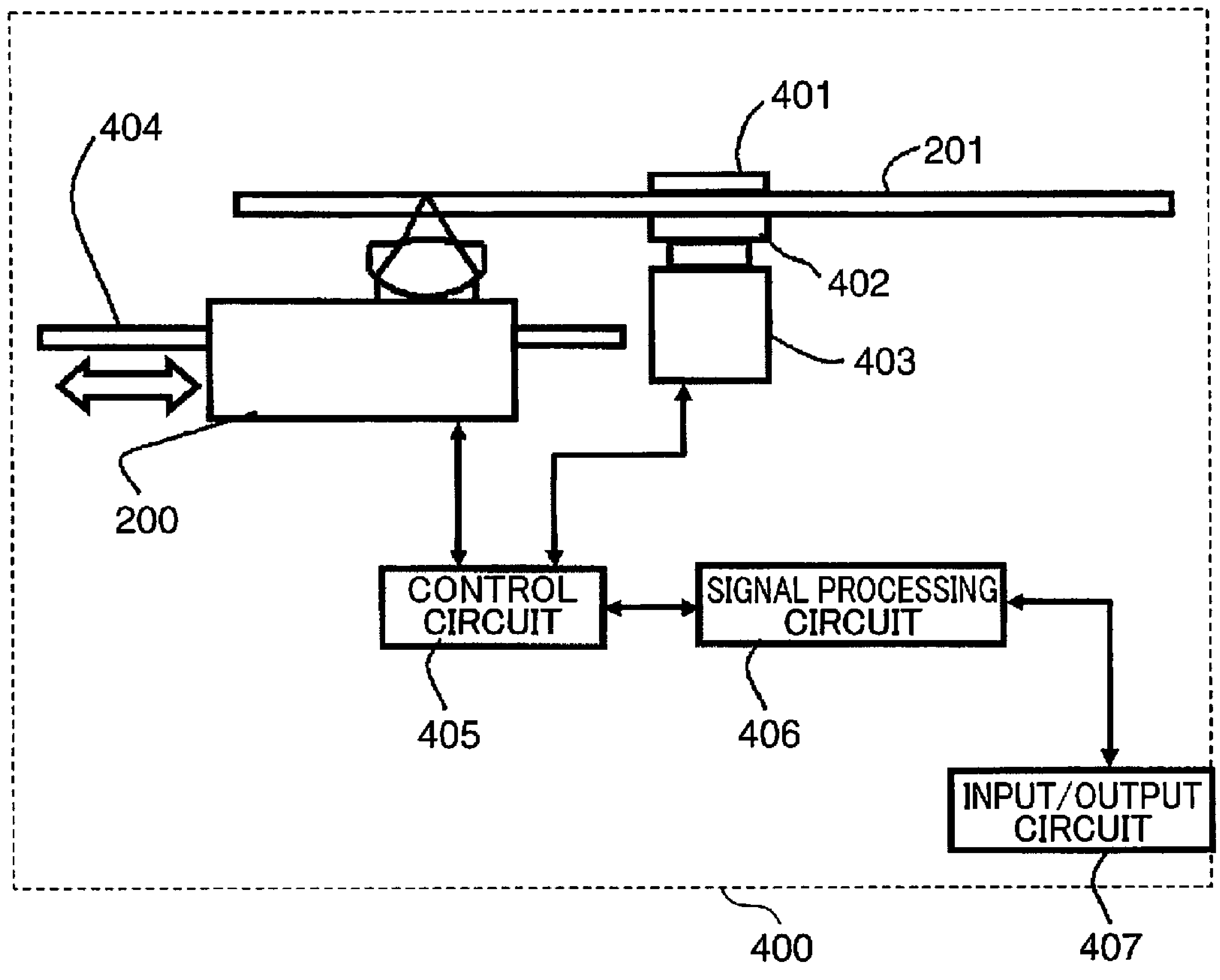

401
404
201
402
403
200
CONTROL CIRCUIT
SIGNAL PROCESSING CIRCUIT
405
406
INPUT/OUTPUT CIRCUIT
400
407

FIG.19A

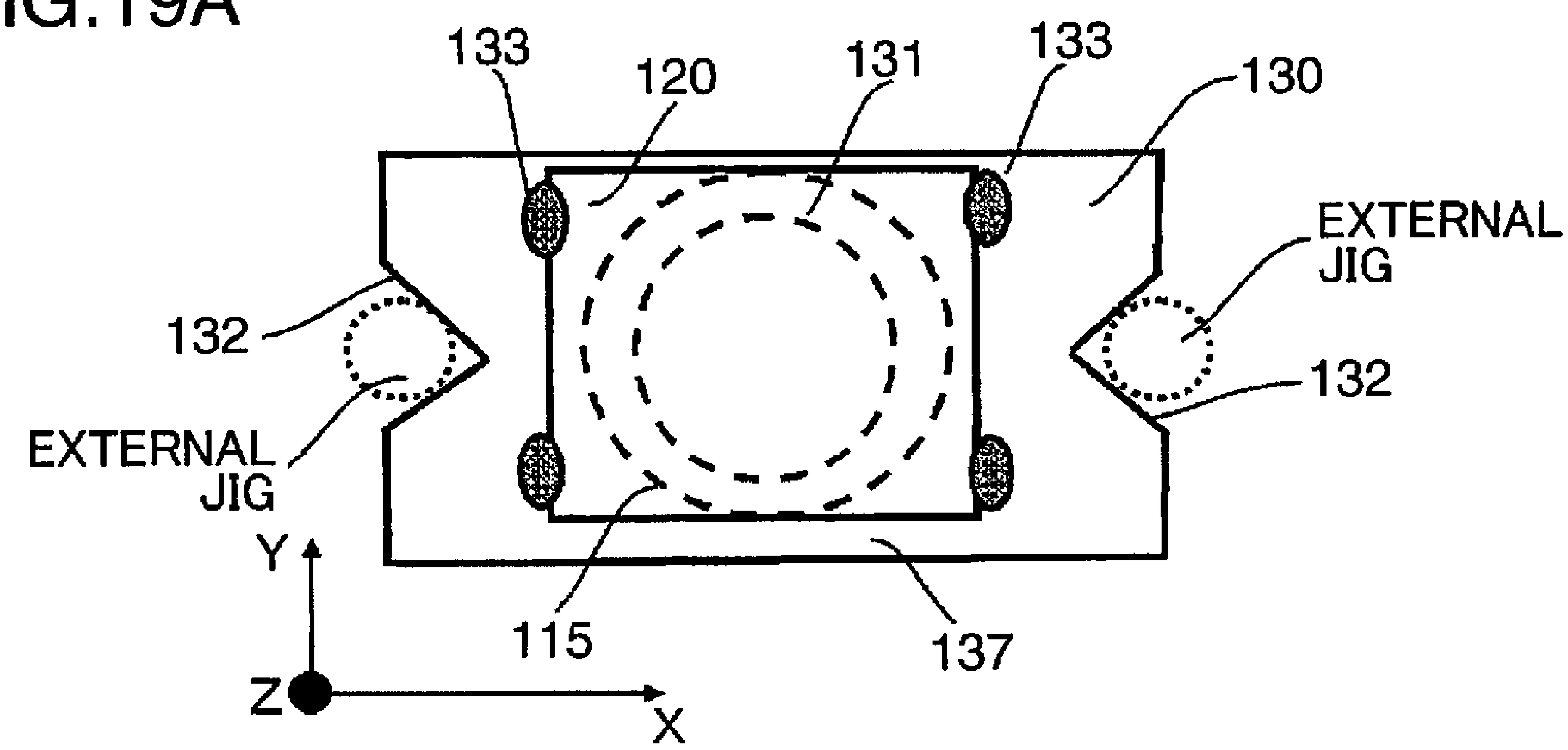



FIG.19B

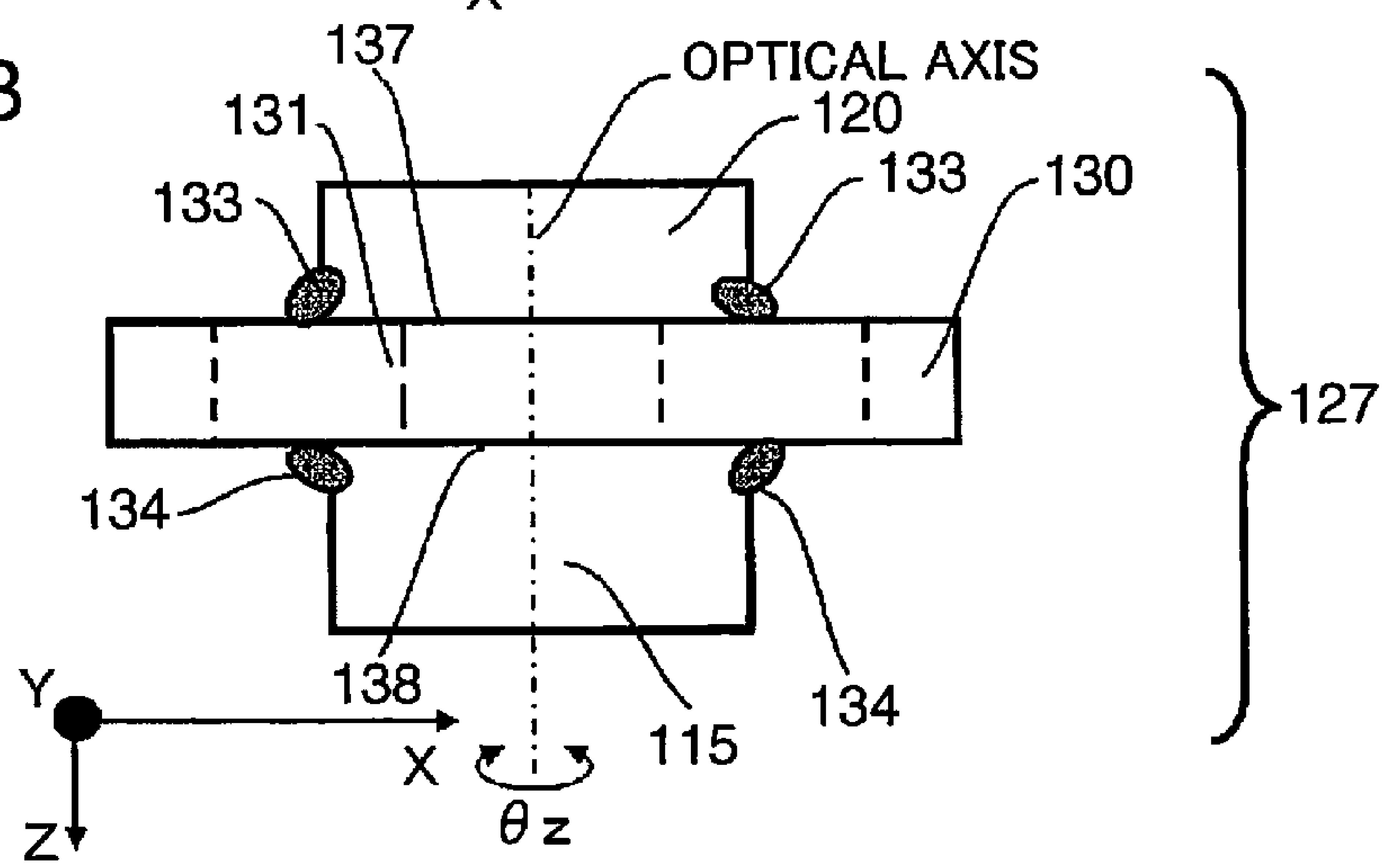



FIG.19C

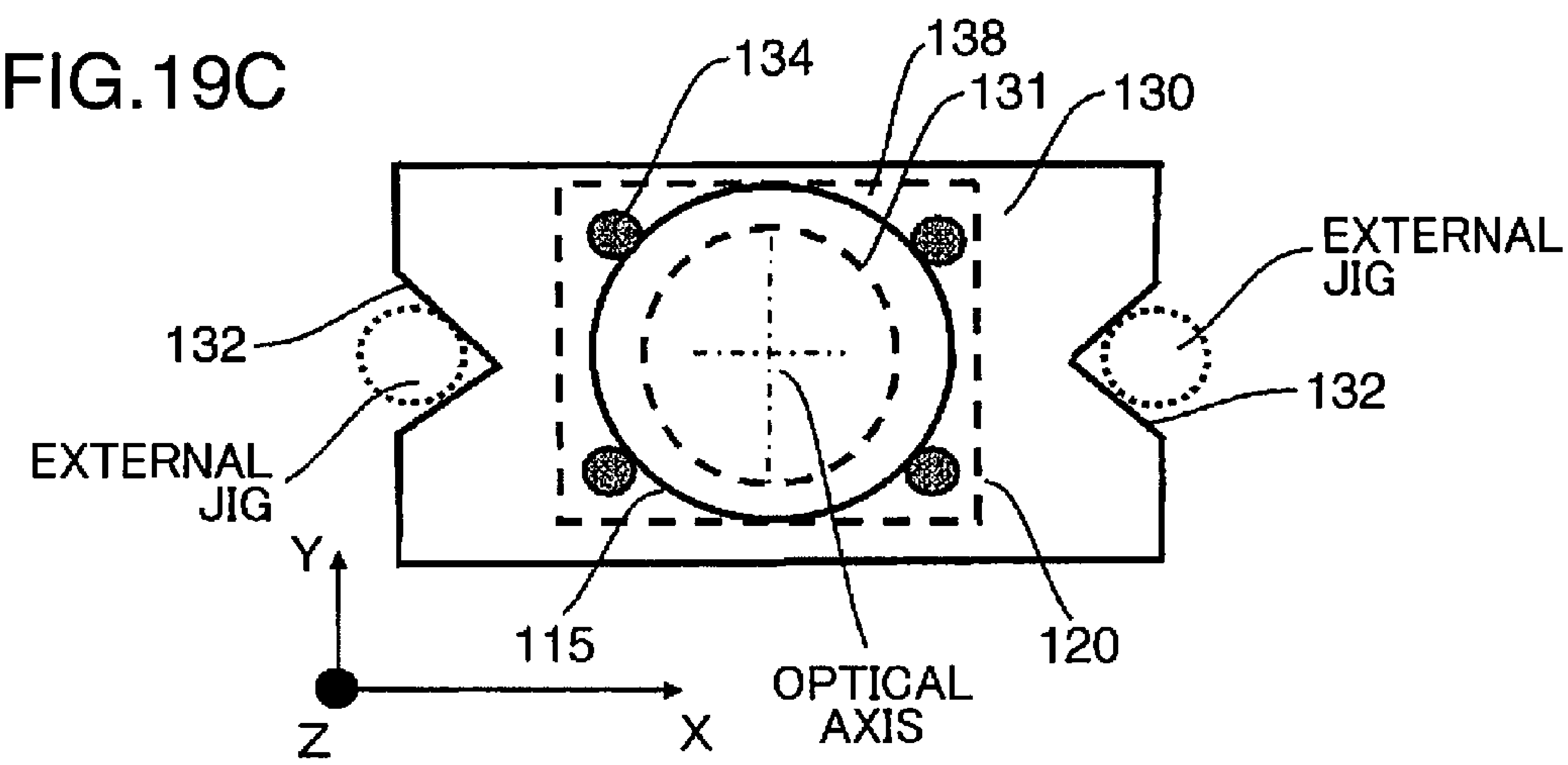


FIG.20A

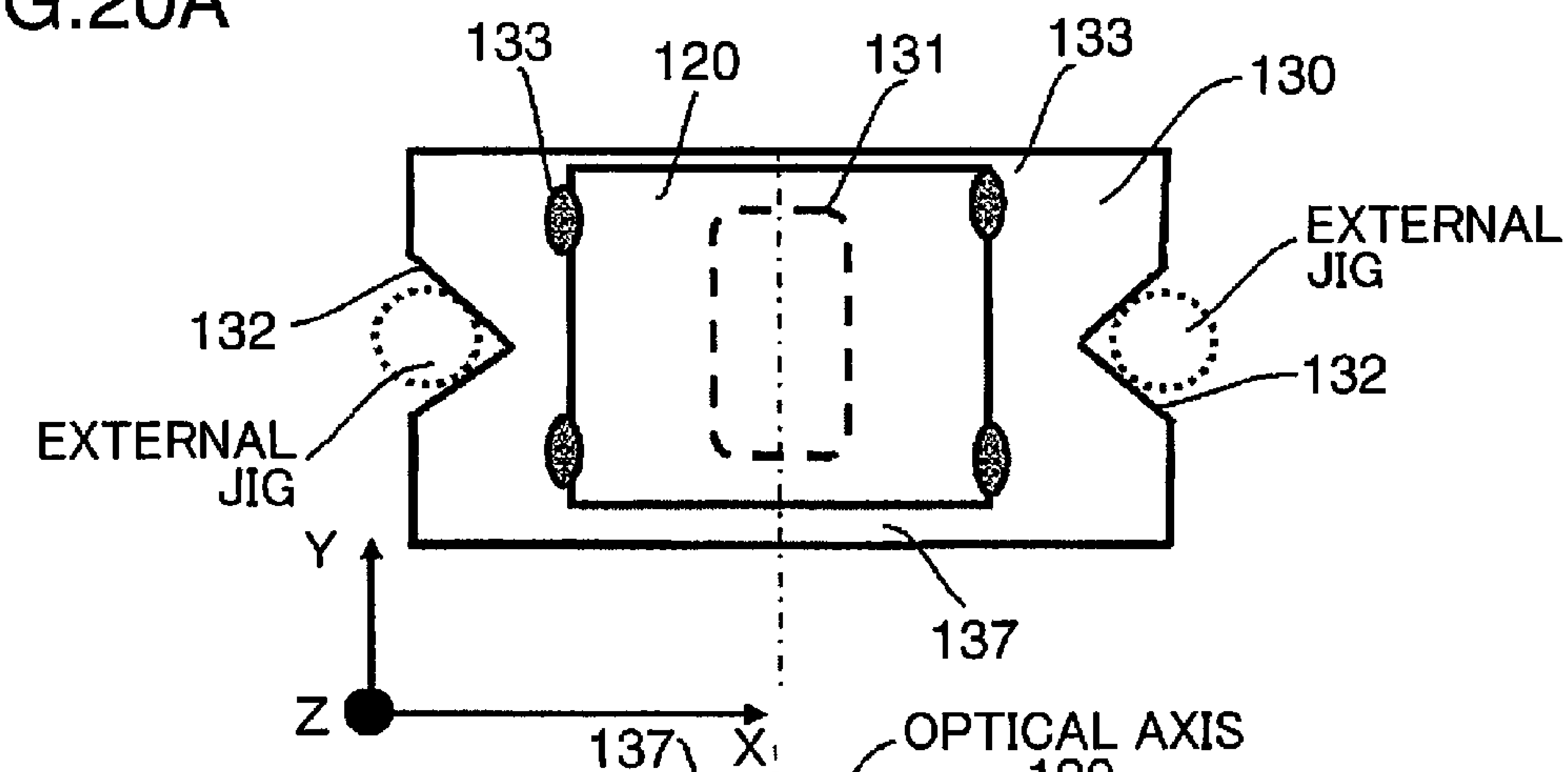



FIG.20B

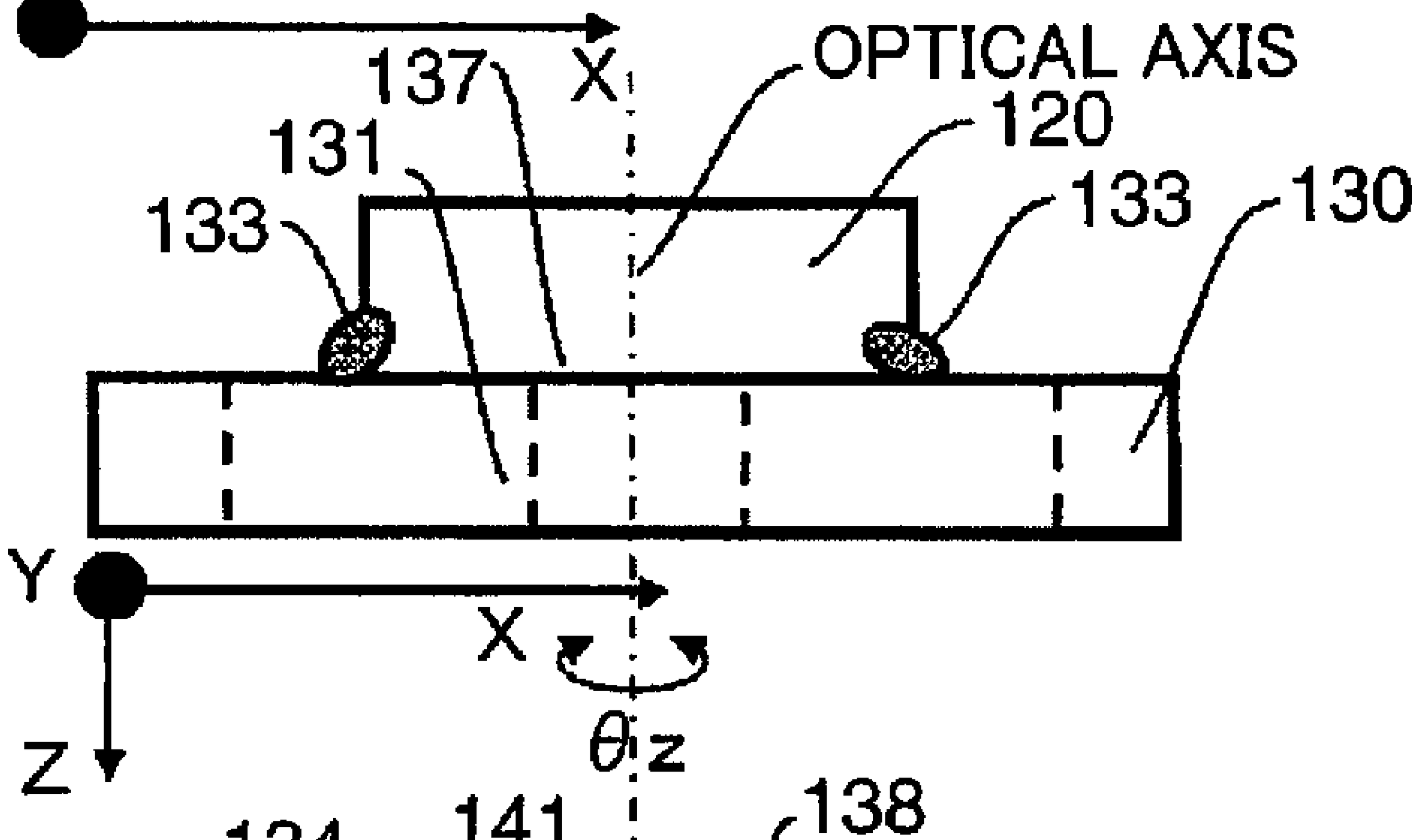



FIG.20C

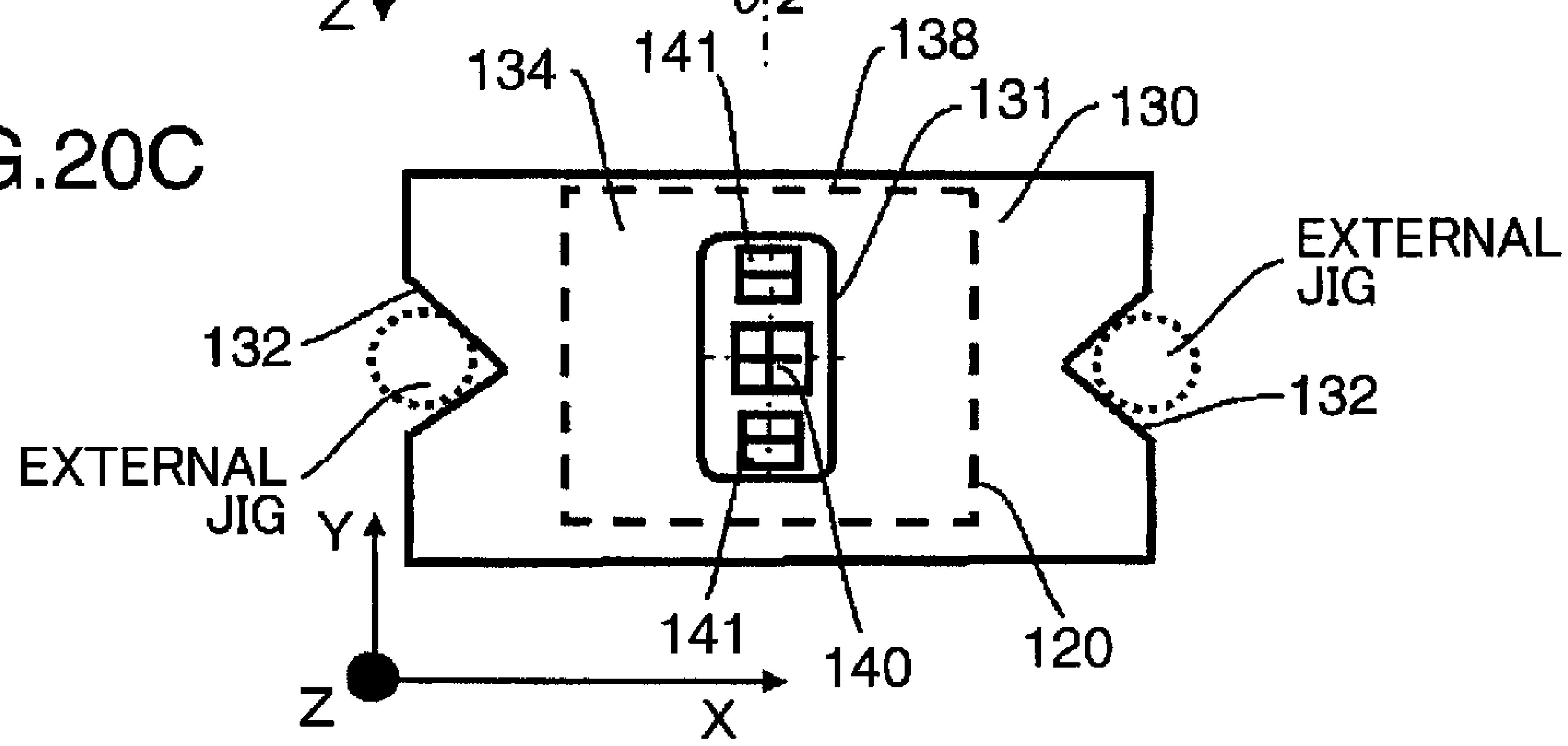



FIG.20D

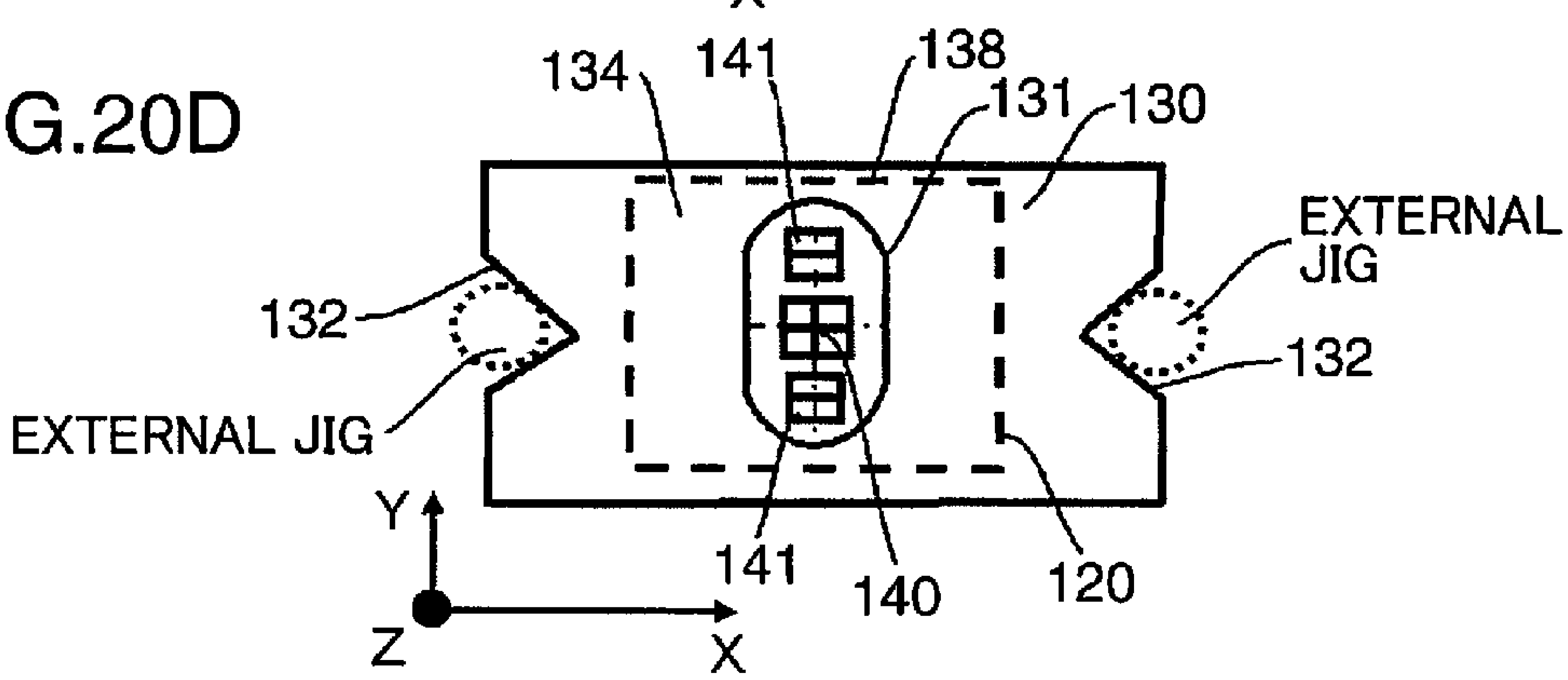


FIG.21A

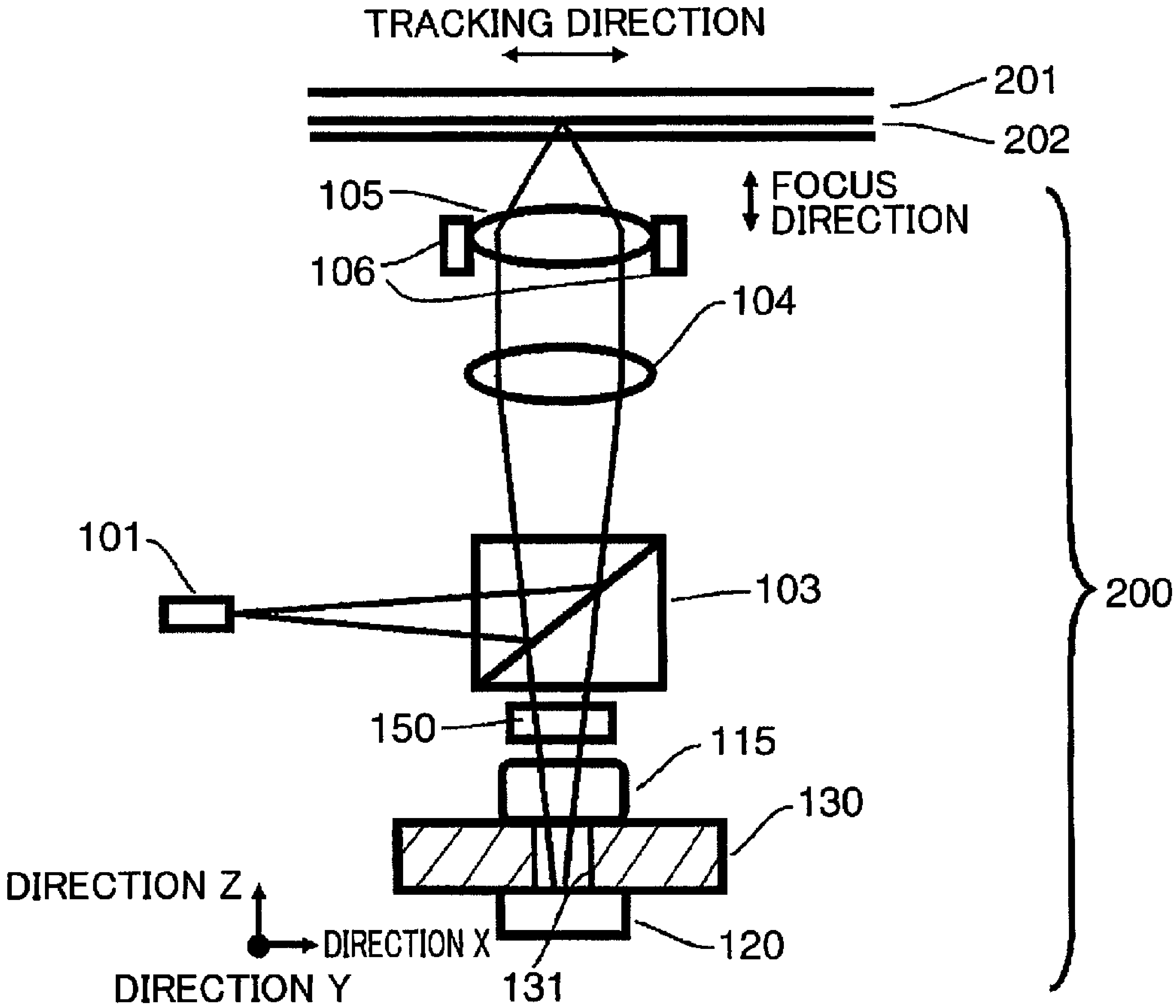



FIG.21B

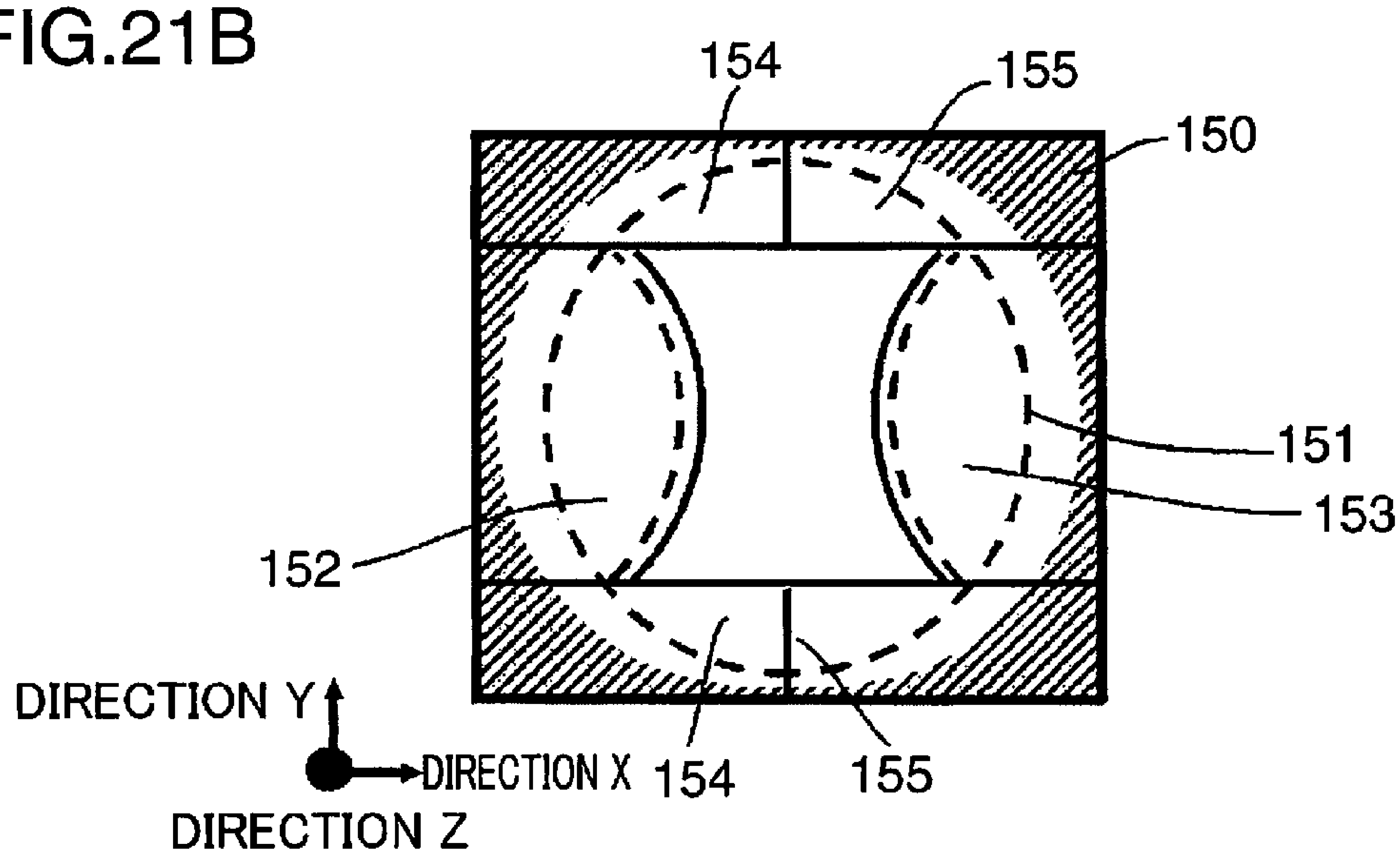


FIG.22A

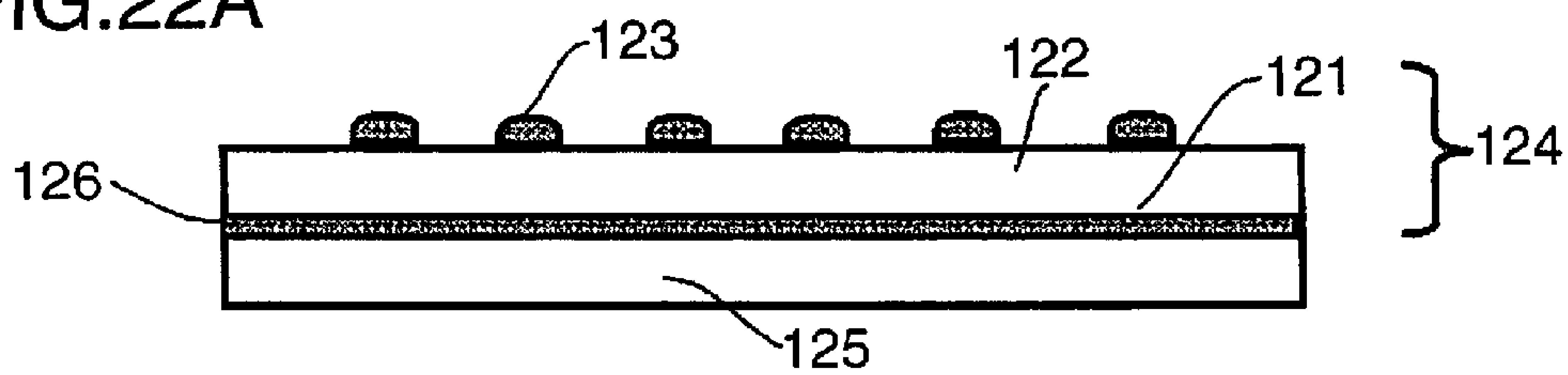



FIG.22B

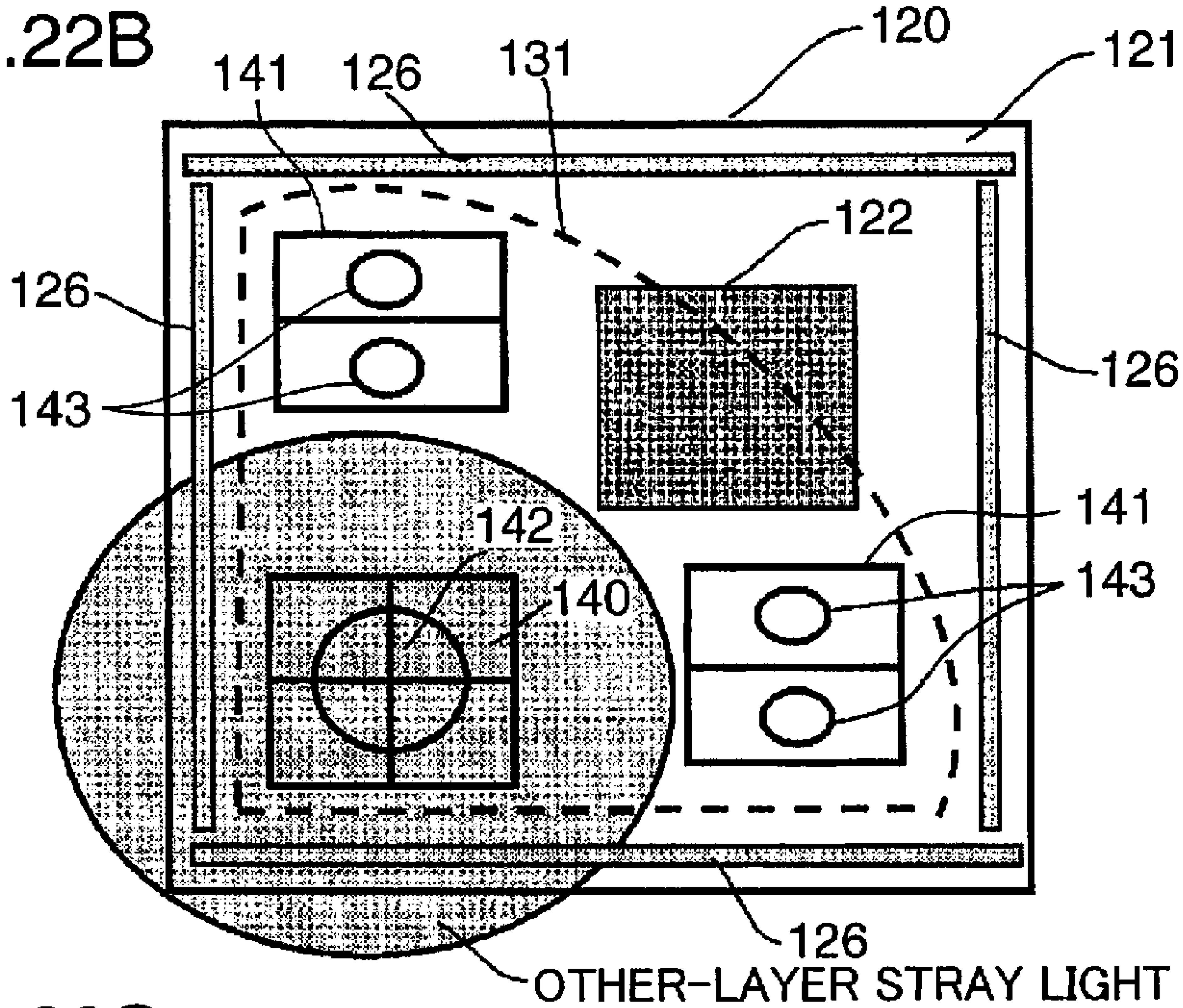



FIG.22C

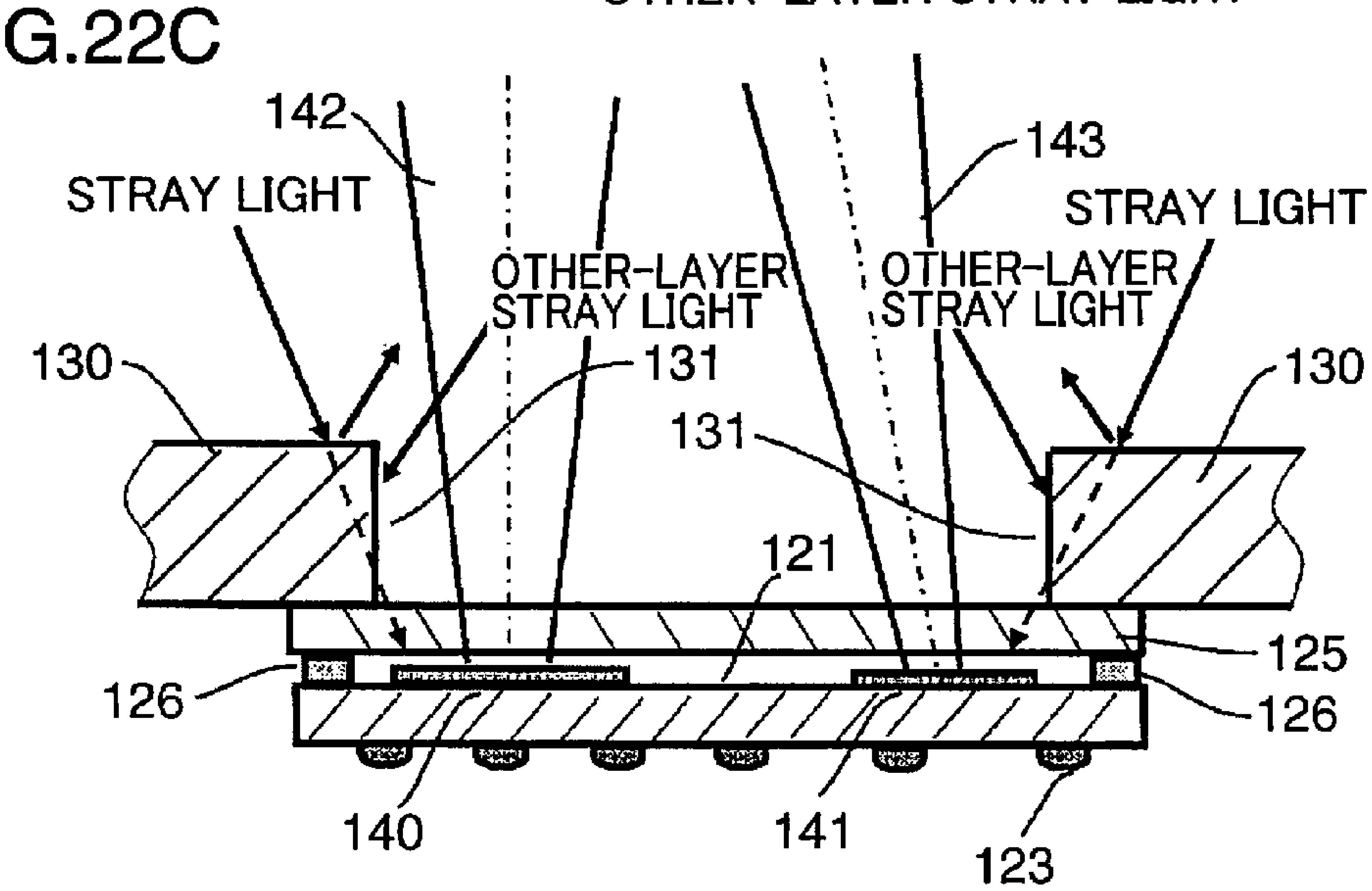


FIG.23A

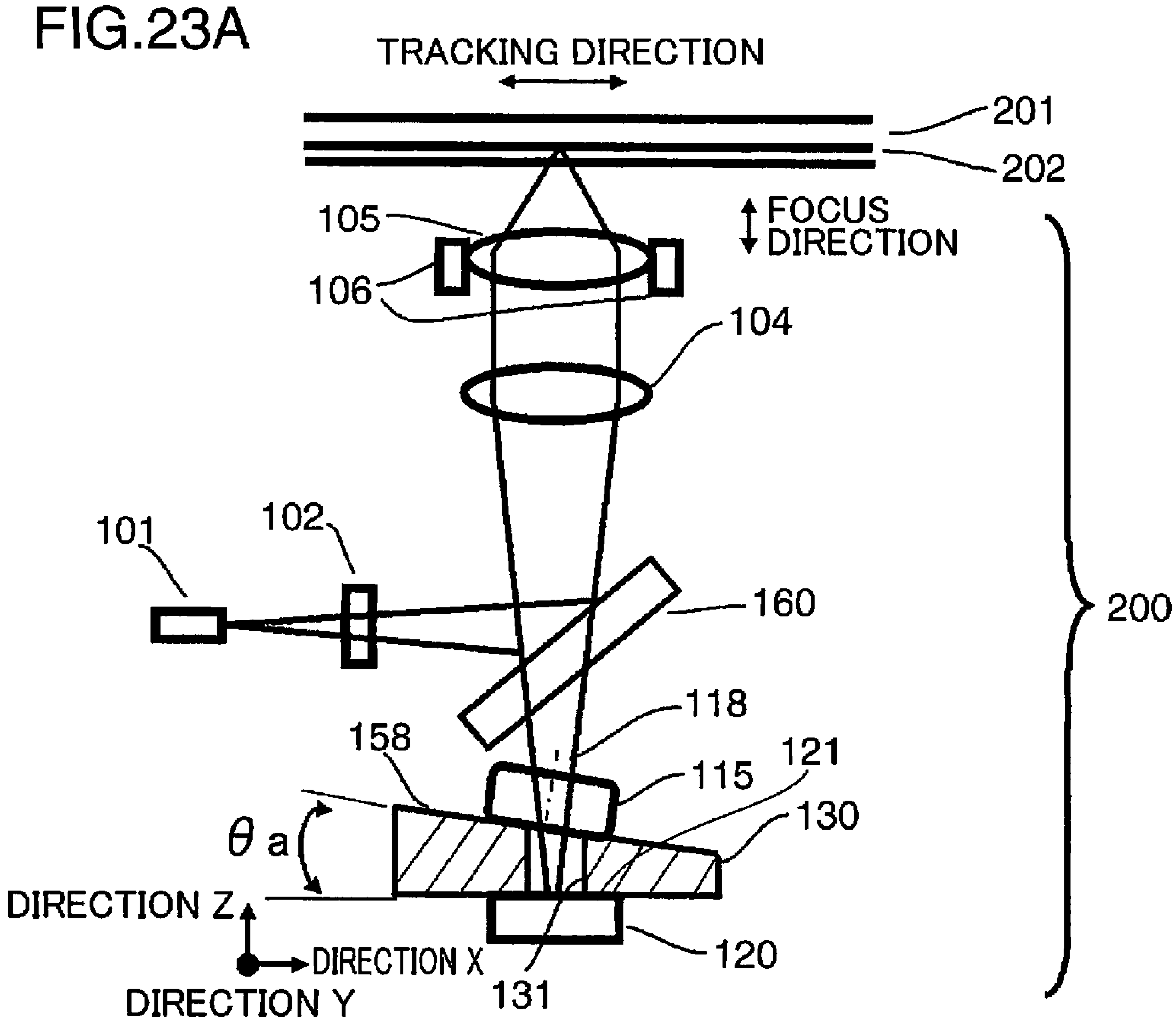



FIG.23B

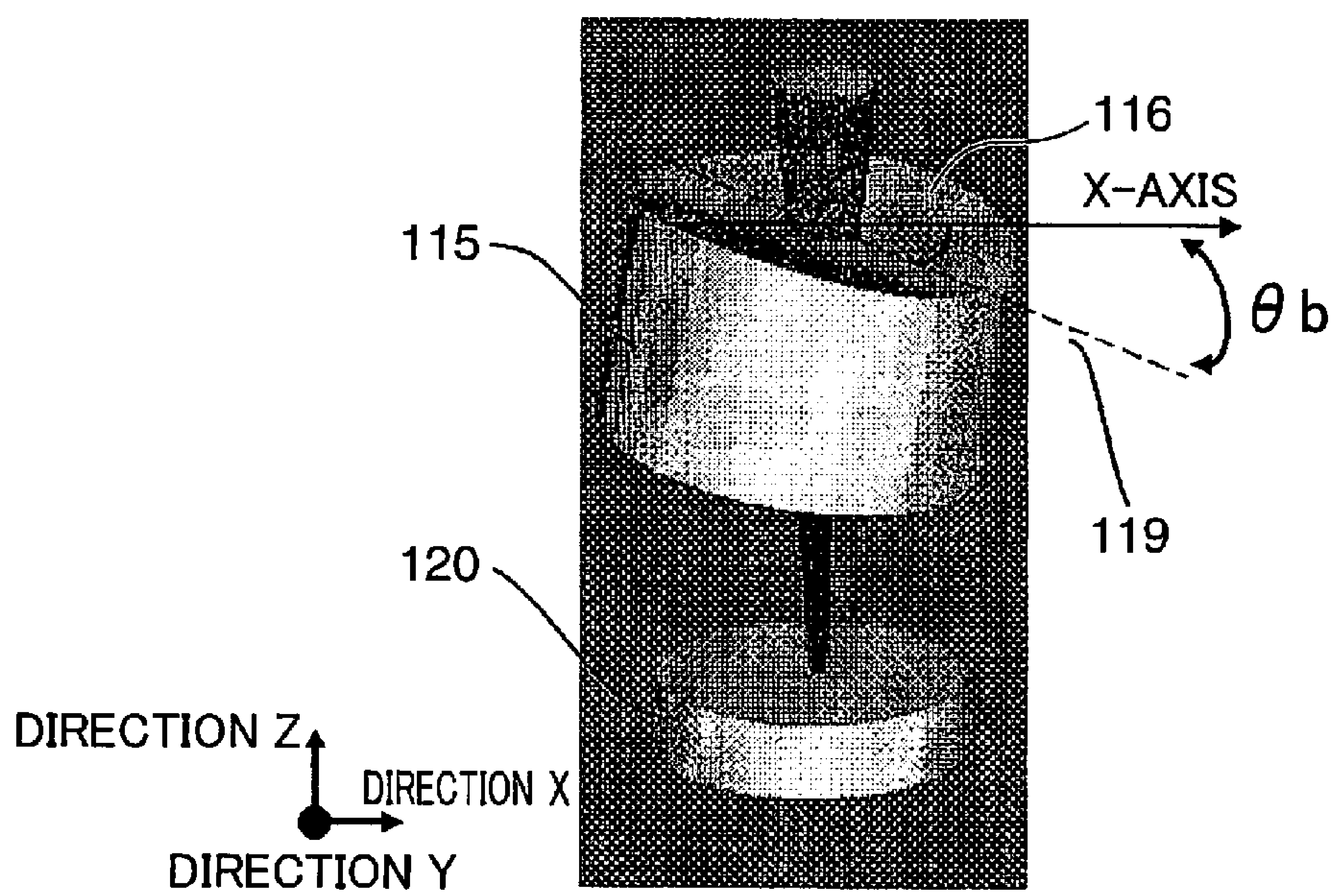


FIG.24A

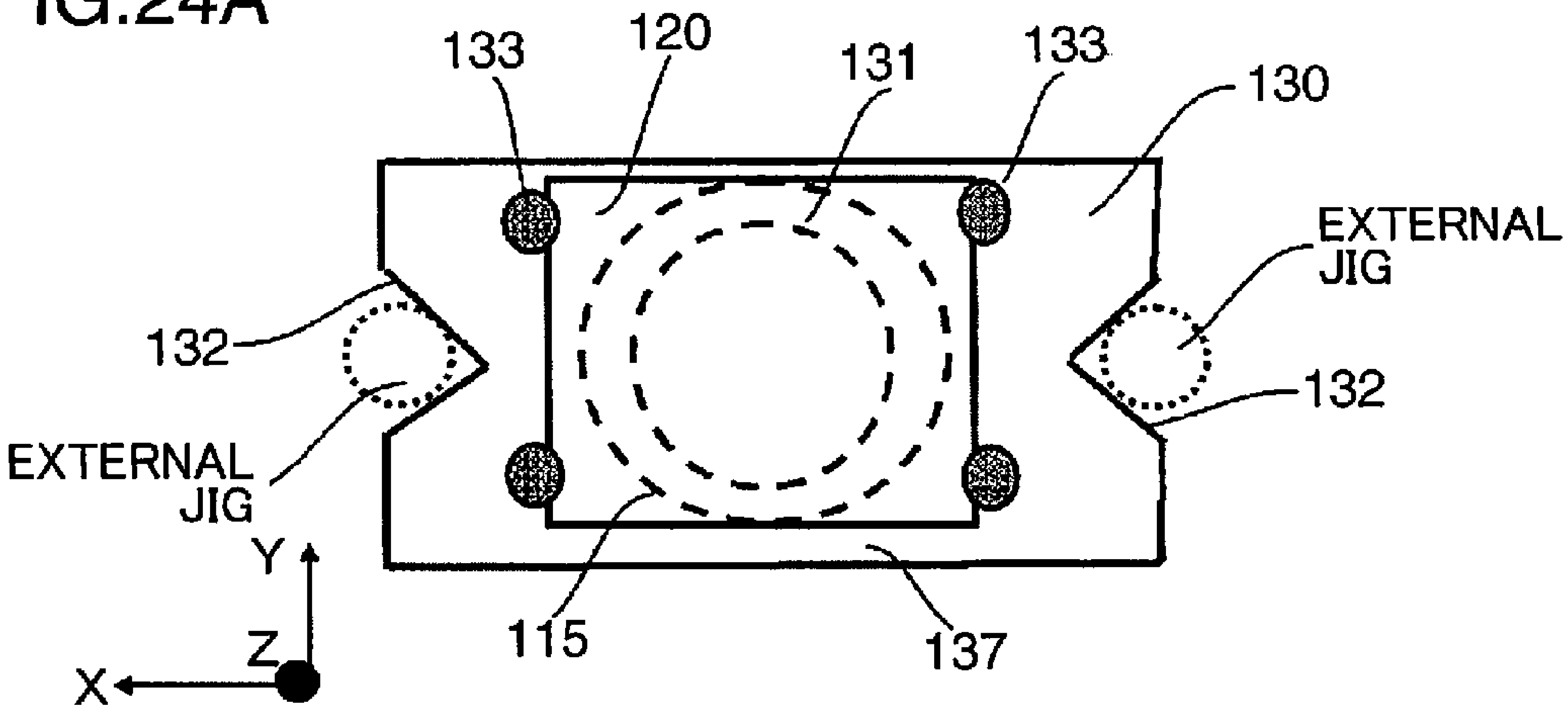



FIG.24B

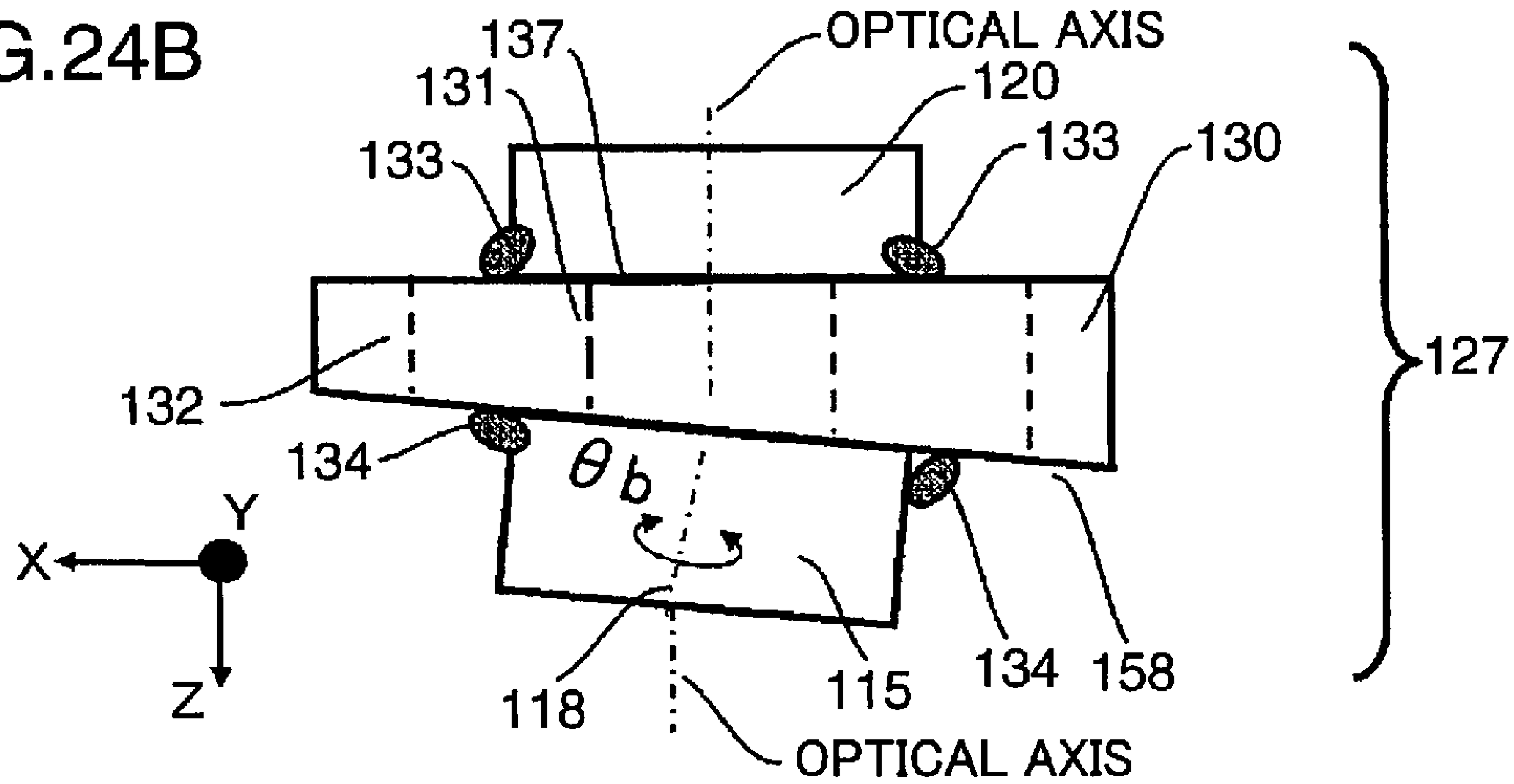



FIG.24C

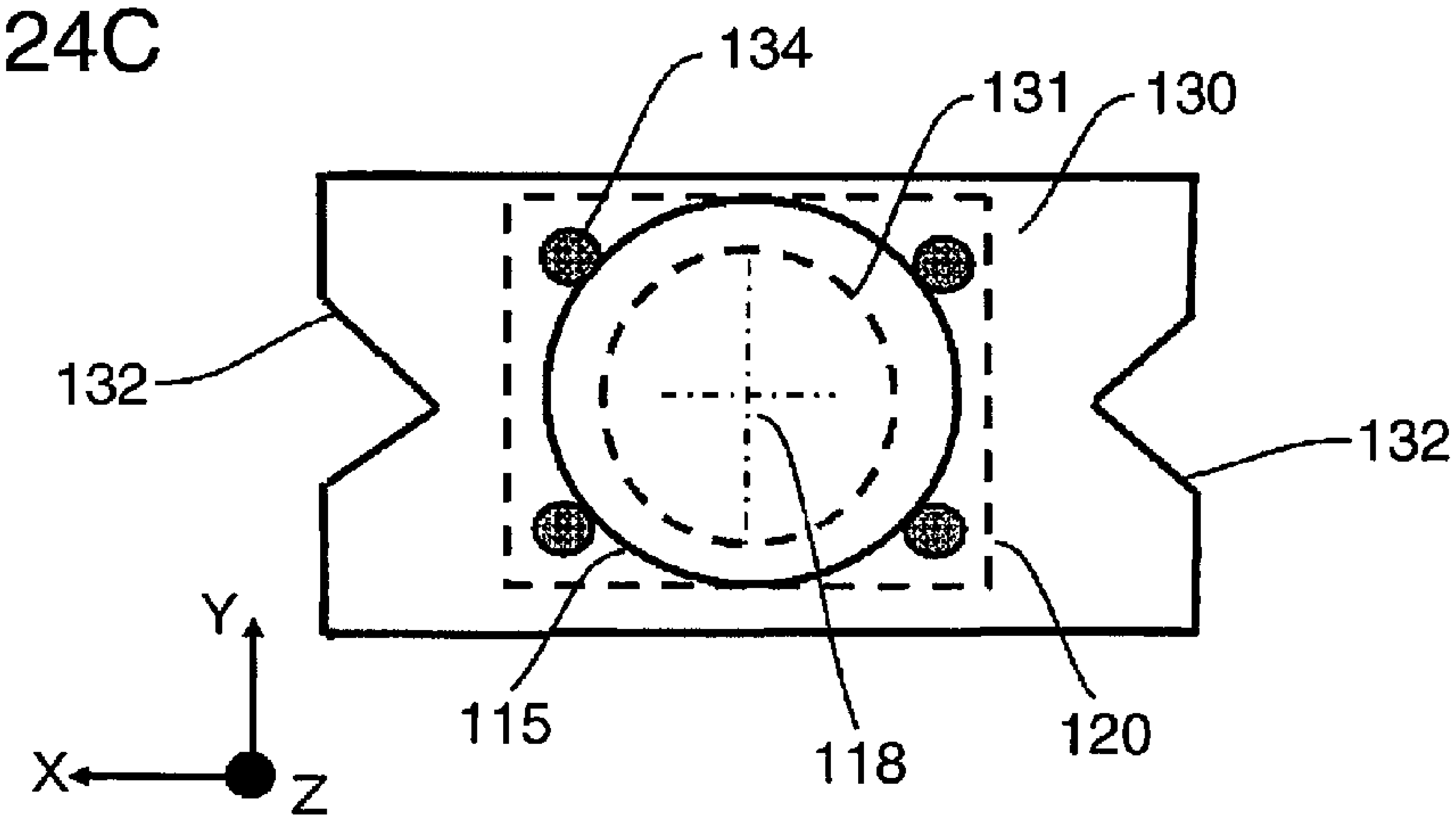


FIG.25A

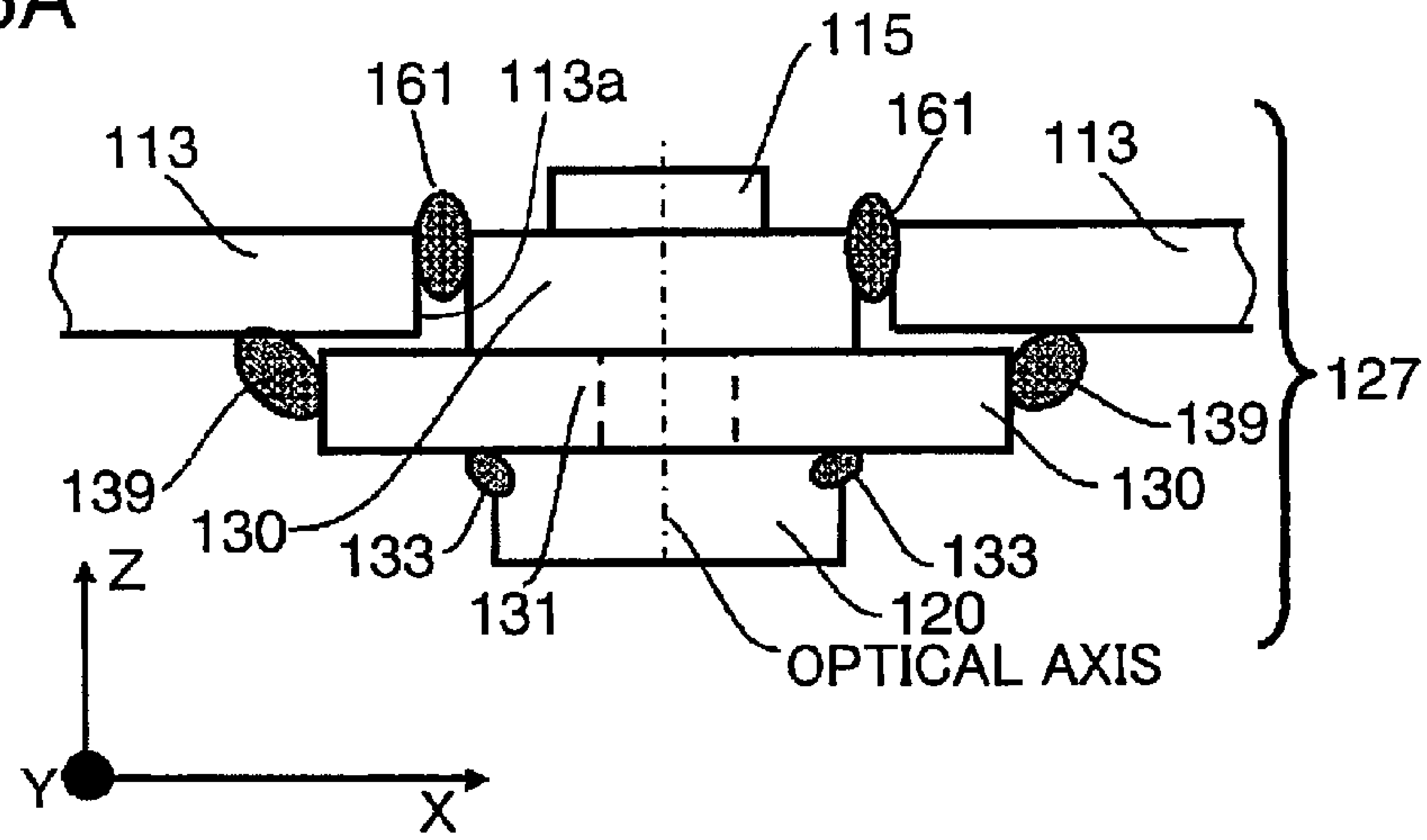



FIG.25B

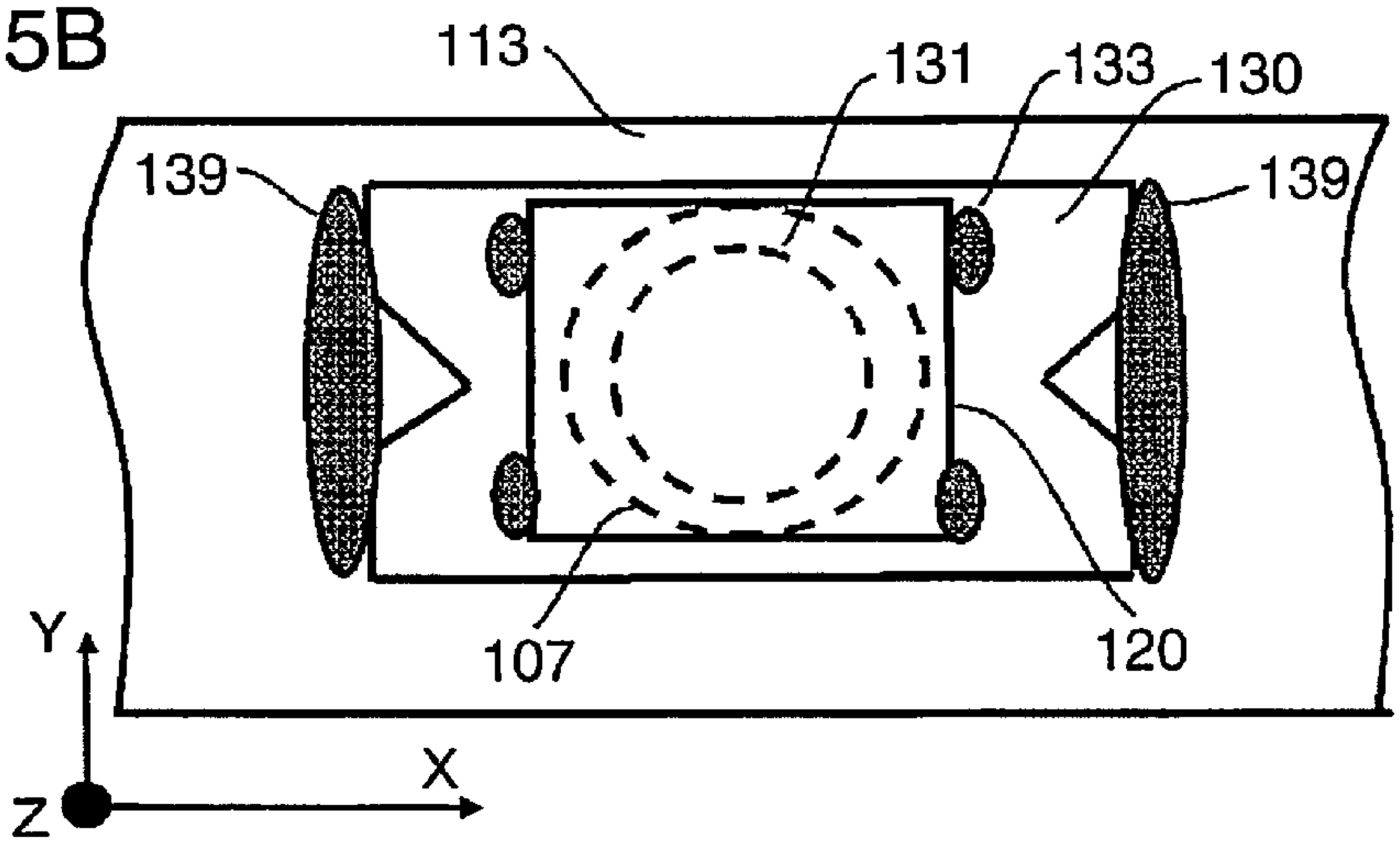



FIG.25C

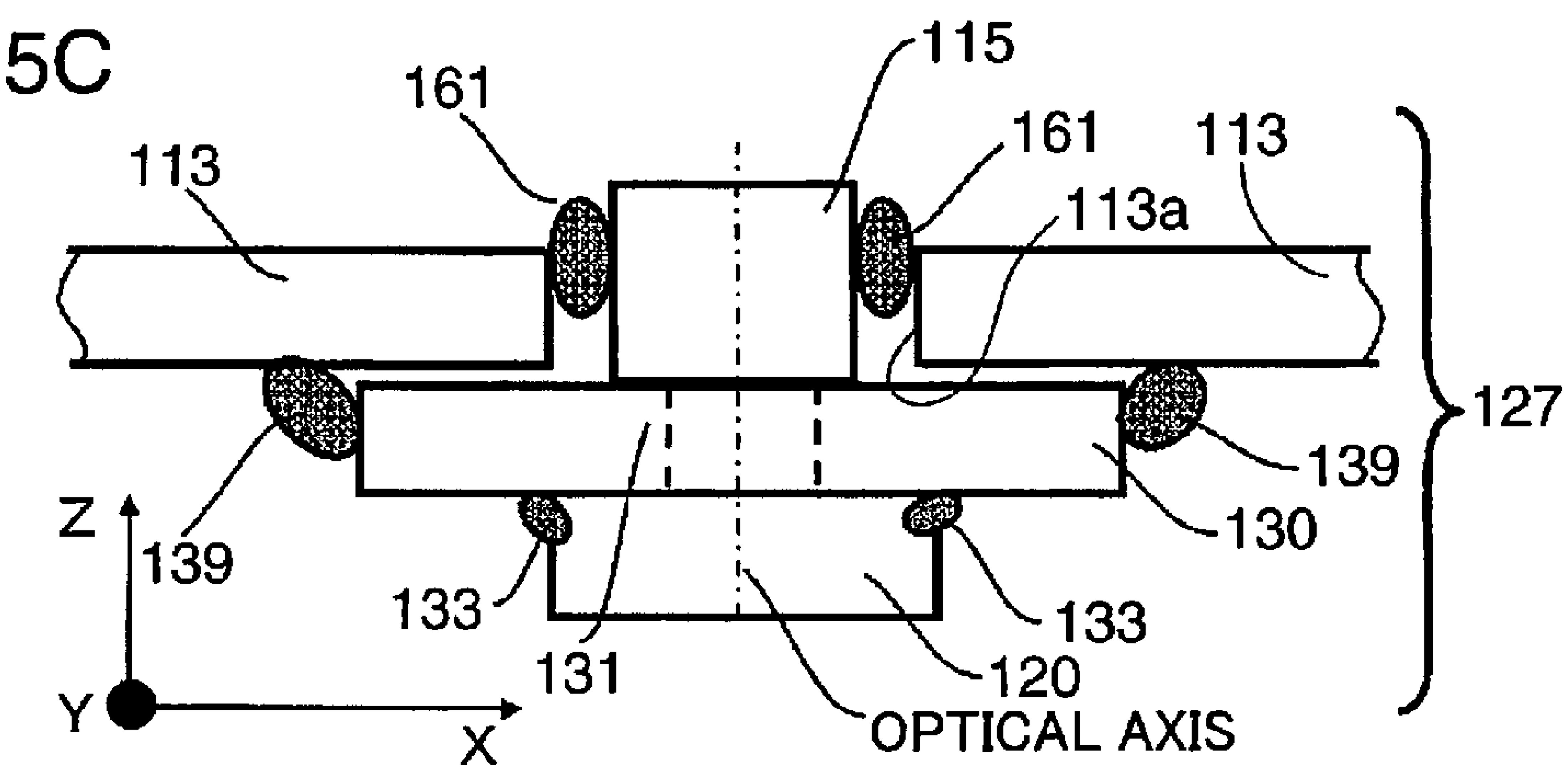


FIG.26

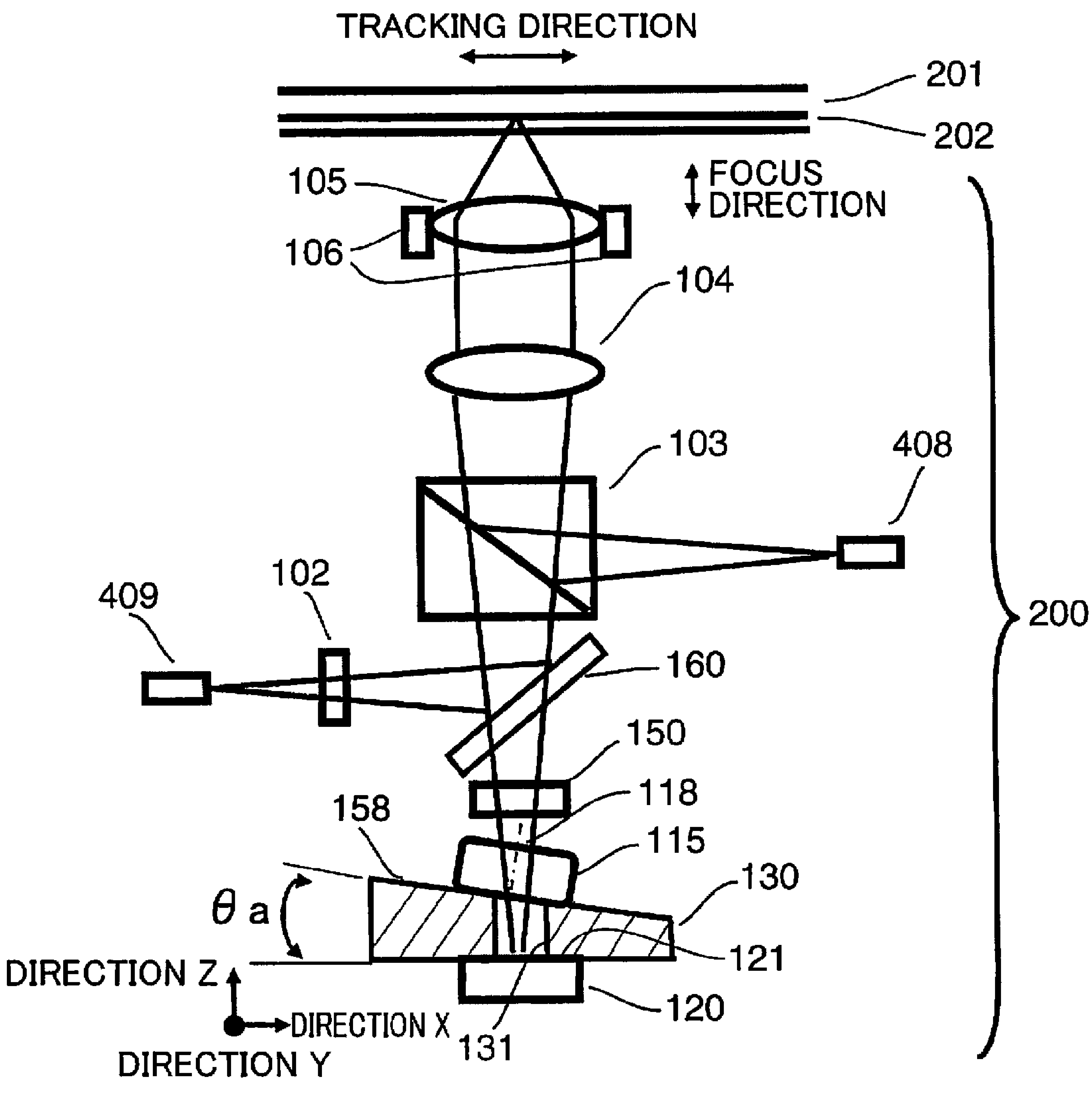

TRACKING DIRECTION
201
202
105
FOCUS DIRECTION
106
104
103
408
409
102
200
160
150
118
158
115
130
θ a
121
DIRECTION Z
120
DIRECTION X
131
DIRECTION Y

FIG.27

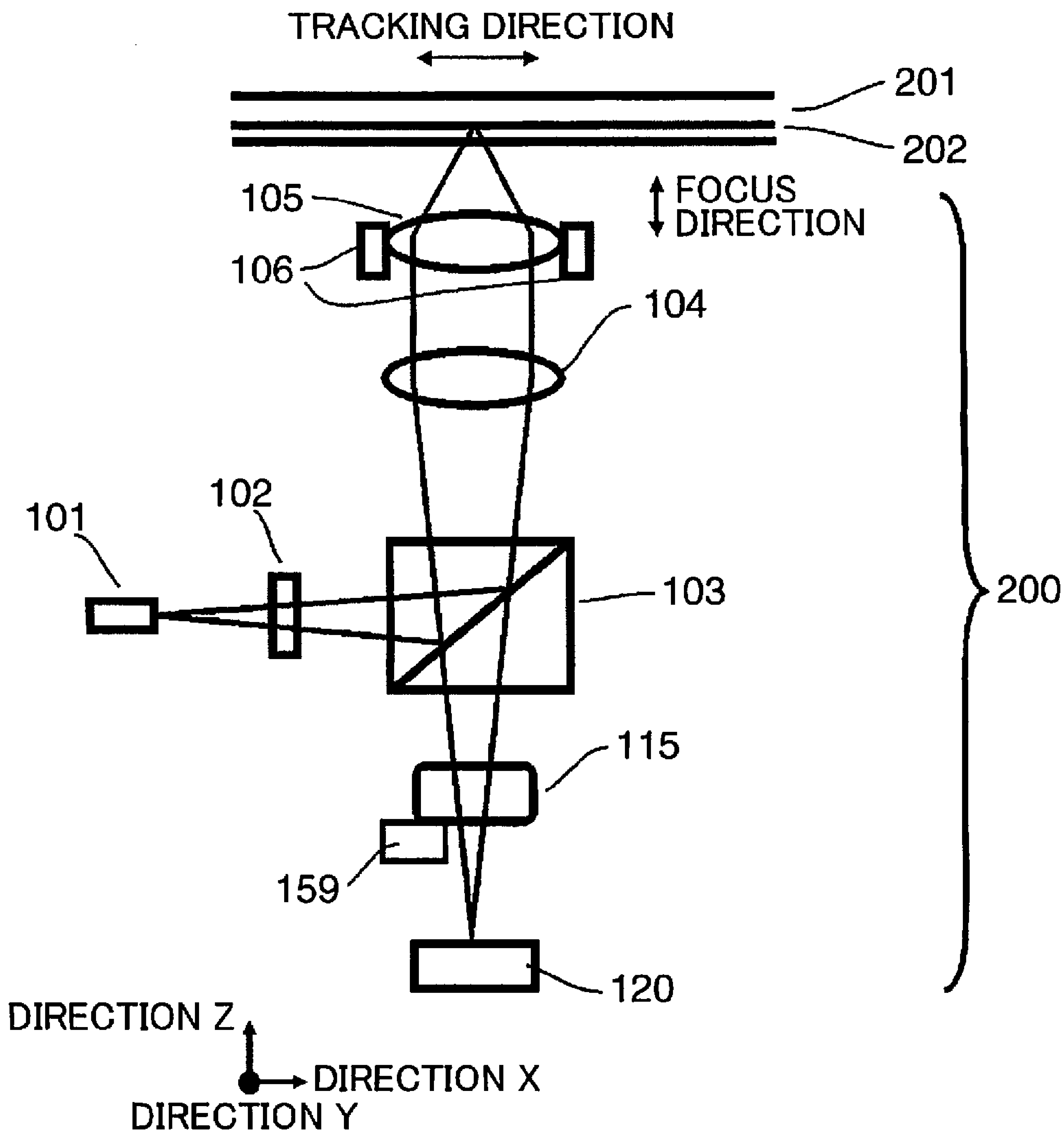

TRACKING DIRECTION
201
202
105
106
FOCUS DIRECTION
104
102
101
103
200
115
159
120
DIRECTION Z
DIRECTION X
DIRECTION Y

FIG.28

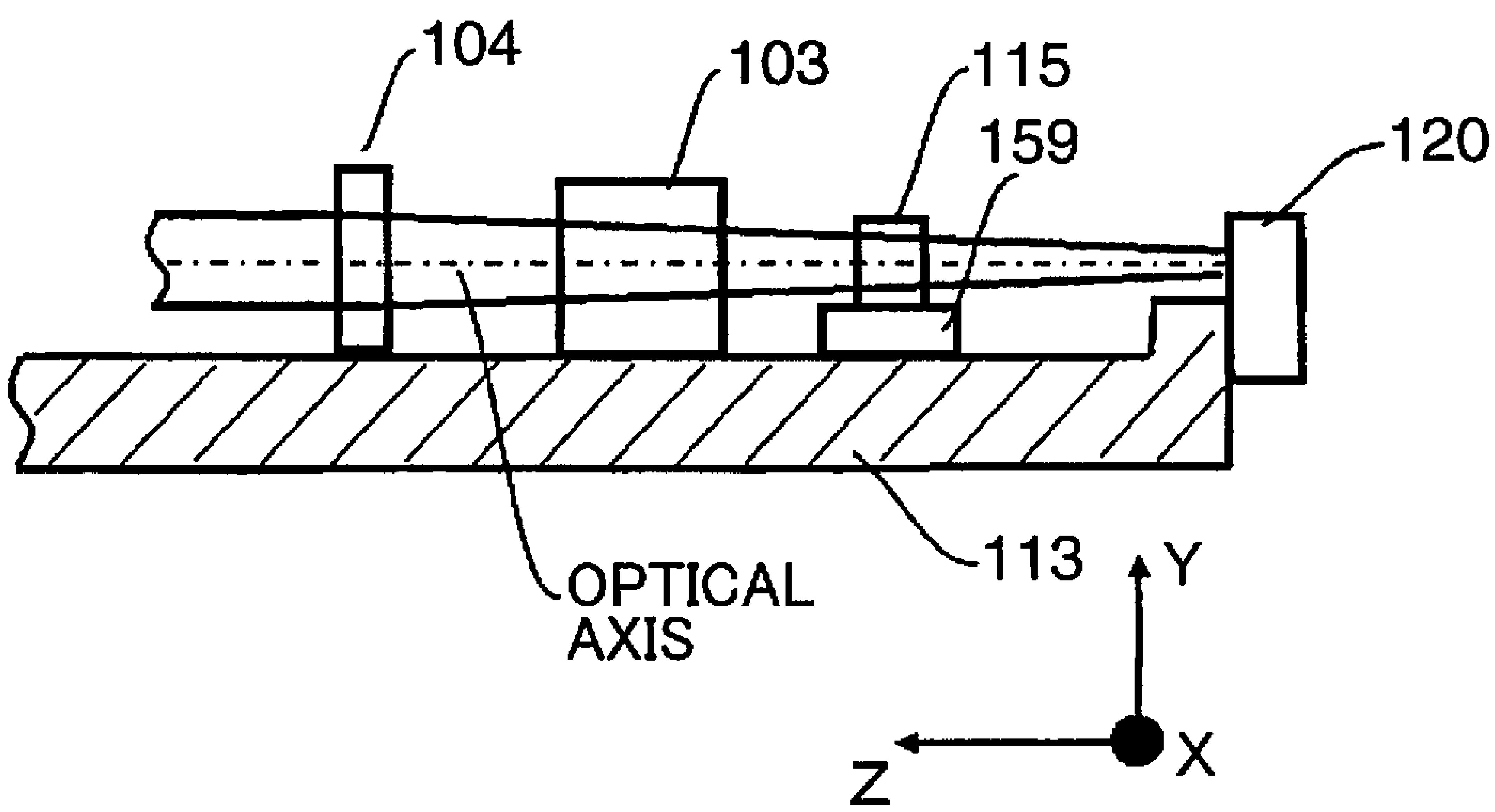
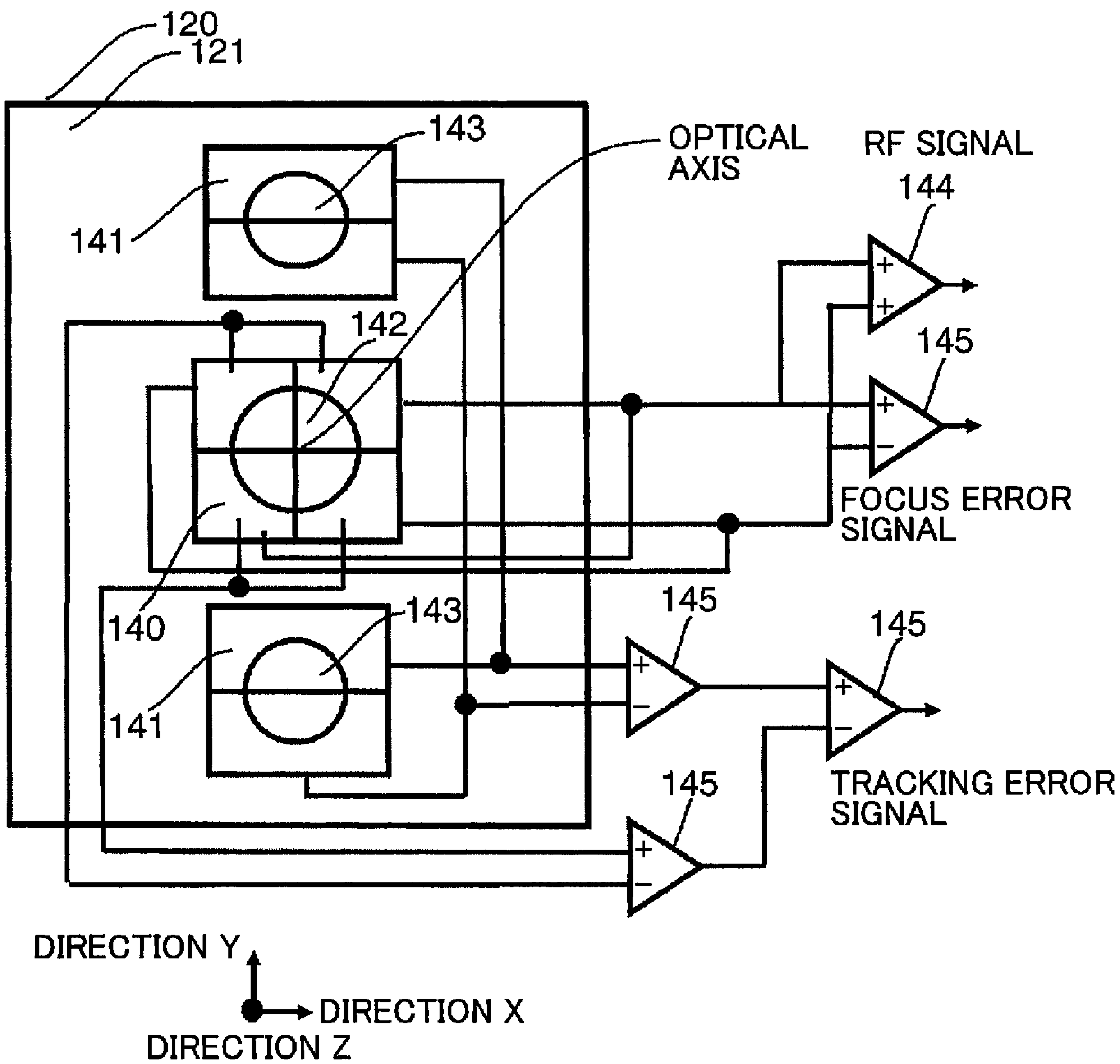


FIG.29


120
121
143
141
142
OPTICAL AXIS
RF SIGNAL
144
145
FOCUS ERROR SIGNAL
140
143
141
145
145
TRACKING ERROR SIGNAL
145
DIRECTION Y
DIRECTION X
DIRECTION Z

# OPTICAL HEAD AND OPTICAL INFORMATION DEVICE

## TECHNICAL FIELD

The present invention relates to an optical head and an optical information device that record information on an information recording medium such as an optical disk, an optical card or the like, or that reproduce recorded information therefrom.

## BACKGROUND ART

Known conventional optical heads include optical heads configured in such a manner that a cylindrical lens and a lens holder are integrated together but the cylindrical lens and a light detector are separated from each other (for instance, Patent Document 1).

FIG. **27** and FIG. **28** illustrate an optical head, and a light-detection section thereof, disclosed in Patent Document 1.

In FIG. **27**, a beam of light emitted by a semiconductor laser **101** is split into a plurality of different light beams by a diffraction grating **102**. The light beams passing through the diffraction grating **102** are reflected by a beam splitter **103**, and are converted into parallel light beams by a collimator lens **104**. These light beams enter an objective lens **105** and become so-called three-beam converging light that is irradiated onto an optical disk **201**. An objective lens actuator **106** drives the objective lens **105** in the optical axis direction (focus direction) and the radial direction of the optical disk **201**. The beams of light reflected and diffracted by an information layer **202** of the optical disk **201** pass again through the objective lens **105**, and then through the beam splitter **103**. The light beams that traverse the beam splitter **103** pass through a cylindrical lens **115**, and is incident on a light detector **120**.

FIG. **28** is a partial schematic diagram of an optical head **200**. An optical base **113** holds the semiconductor laser **101**, the diffraction grating **102**, the beam splitter **103**, the collimator lens **104** and an objective lens actuator **106**. The cylindrical lens **115** is disposed in such a manner that a concave cylindrical lens surface thereof, having negative power (concave lens effect), is on the side of the light detector. The position of the cylindrical lens **115** in the optical axis direction can be adjusted along the optical base **113** in a state where the cylindrical lens **115** is fixed to the lens holder **159**. The cylindrical lens **115** is held in this state by an external jig. The position of the light detector **120** can be adjusted within a plane (X-Y plane) that is perpendicular to the optical axis, in a state where the light detector **120** is held by an external jig.

FIG. **29** illustrates schematically a light-receiving surface **121** of the light detector **120**. A light beam that transmits the cylindrical lens **115** is received at a four-quadrant light-receiving region **140**. The differences between the sum signals of diagonally-opposing regions within the four-quadrant light-receiving region **140** are computed to detect thereby a so-called focus signal. An RF signal is also detected by computing the sum signals from the four-quadrant light-receiving region **140**.

A push-pull signal resulting from computing the signals obtained from the four-quadrant light-receiving region **140**, plus signals corresponding to the quantity of light that is received at sub-beam light-receiving regions **141**, are computed by a summing amplifier **144** and a differential amplifier **145**. The three-beam method (so-called DPP method) yields a tracking error signal on the basis of which tracking servo is carried out in order to cause the objective lens **105** to follow a track in the information layer **202**.

In order to secure symmetry and linearity in the focus error signal, the light detector **120** is disposed spaced apart from the concave cylindrical lens surface of the cylindrical lens **115**. To that end, the position of the light detector **120**, alone or together with the holder, is adjusted within the X-Y plane. This position adjustment is carried out while referring to the detection signal from the light detector **120**, in such a manner that a light beam enters substantially the center of the four-quadrant light-receiving section **140**. Thereafter, the light detector **120** (or holder) is fixed to the optical base **113**.

The lens holder **159** to which the cylindrical lens **115** is fixed is held in a state whereby the lens holder **159** can move over the optical base **113** in the optical axis direction. The relative position with respect to the light detector **120** is adjusted by adjusting the cylindrical lens **115** in direction Z. The optical base **113** and a lens holder **159** are then fixed together. Through this adjustment in direction Z, the objective lens **105** and the information layer **202** become positioned at a just focus distance, and the focus error signal offset is cancelled. Specifically, the output of the focus error signal at the just focus distance is 0.

Optical heads are expected to be developed wherein the optical head can support recording or reproduction to/from small, high recording-density multilayer optical disks having two or more recording layers.

In order to support recording and reproduction to/from high recording-density multilayer optical disks, and to reduce the size of the optical head, large negative lens power is required to be achieved by forming a concave lens surface, having a small radius of curvature, on the cylindrical lens.

In an optical system having an optical head, however, it is impossible to avoid small errors during adjustment of the position of the light detector in directions X-Y and during adjustment of the position of the cylindrical lens in direction Z. As a result, a relative positional error between the light detector and the cylindrical lens arises on account of the positional offset of the cylindrical lens in direction Z and directions X-Y. This gives rise in turn to error in the position of the cylindrical lens in direction Z.

When such an optical system is fitted with a cylindrical lens having high lens power, such as the one described above, magnification by the detection optical system varies significantly depending on the relative positional error, and sub-beams may bear away from the sub-beam light-receiving regions of the light detector. In the light detector, angle error and positional error, in directions X-Y, with respect to the optical axis, cause the sub-beams to bear away, by a greater distance, from the sub-beam light-receiving regions, and give rise to significant deterioration of the quality of the tracking error signal, which may impair recording and reproduction performance. Thus, reducing the size of detection optical systems equipped with high-power cylindrical lenses is extremely difficult in optical systems having conventional optical heads.

Patent Document 1: JP 10-003683 A

## SUMMARY OF THE INVENTION

It is an object of the present invention to provide an optical head that is small and in which signal characteristics can be improved upon recording and reproduction to/from a multilayer optical information recording medium of high recording density.

An optical head according to an aspect of the present invention comprises a light source that emits a light beam; an objective lens that condenses, in the form of converging light, the light beam emitted by the light source, onto an information recording medium; a cylindrical lens, onto which a reflected light beam that is reflected by the information recording medium is incident, and which generates astigmatism for forming a focus error signal; a light detector that receives the reflected light beam passing through the cylindrical lens; and a holder that holds the cylindrical lens and the light detector. The holder has a first main face and a second main face that extend in directions that intersect the optical axis of the reflected light beam, such that the cylindrical lens is bonded to the first main face and the light detector is bonded to the second main face.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram illustrating schematically an optical system of an optical head according to a first embodiment of the present invention.

FIG. **2**A is a side-view diagram illustrating schematically a light detector provided in the optical head according to the first embodiment of the present invention, FIG. **2**B is a front-view diagram illustrating schematically the light detector, and FIG. **2**C is a side-view diagram illustrating schematically the light detector.

FIG. **3** is a diagram for explaining a light-receiving surface arrangement, and signal extraction, in the light detector provided in the optical head according to the first embodiment of the present invention.

FIG. **4**A is a perspective-view diagram of a cylindrical lens provided in the first embodiment of the present invention, FIG. **4**B is a front-view diagram of the cylindrical lens, and FIG. **4**C is a perspective-view diagram of the cylindrical lens viewed from a different angle from FIG. **4**A.

FIG. **5** is a schematic diagram illustrating partially the optical head according to the first embodiment of the present invention.

FIG. **6**A is a side-view diagram illustrating schematically a detector unit provided in the optical head of the first embodiment of the present invention, FIG. **6**B is a front-view diagram illustrating schematically the detector unit, and FIG. **6**C is a side-view diagram illustrating schematically the detector unit.

FIG. **7** is a diagram for explaining a beam of light that passes through the cylindrical lens.

FIG. **8** is a diagram for explaining a beam of light that passes through the cylindrical lens in a case where the cylindrical lens is disposed in an orientation (cylindrical surface on the side of the light detector) inverted with respect to that in FIG. **7**.

FIG. **9**A is a diagram for explaining the positional relationship between the cylindrical surface and spot diameter at a focal position in the state of FIG. **7**, FIG. **9**B is a diagram for explaining the positional relationship between the cylindrical surface and spot diameter at a focal position in the state of FIG. **8**, FIG. **9**C is a diagram illustrating an example of focus error signal in the case of **9**A, and FIG. **9**D is a diagram illustrating an example of focus error signal in the case of **9**B.

FIG. **10** is a diagram for explaining the shape of a light beam that is incident on a four-quadrant light-receiving region of the light detector of the optical head according to the first embodiment of the present invention.

FIG. **11** is diagram for explaining a fixing method of the detector unit and an optical base in the optical head according to the first embodiment of the present invention.

FIG. **12**A is a diagram illustrating the relationship between spot positional offset and magnification in a detection optical system, and FIG. **12**B is a diagram for explaining the definition of PD balance (direction Y).

FIG. **13**A is a diagram for explaining a beam of light that is incident on a recording layer in a two-layer disk, and FIG. **13**B is a diagram for explaining a beam of light that is incident on a recording layer in a multilayer disk (four-layer disk).

FIG. **14**A is a diagram for explaining other-layer stray light that is incident on a light detector, as a comparative example, and FIG. **14**B is a diagram for explaining other-layer stray light that is incident on the light detector provided in the optical head in the first embodiment of the present invention.

FIG. **15**A is a diagram for explaining an aperture diameter during adjustment of the cylindrical lens in direction Z, in a comparative example, and FIG. **15**B is a diagram for explaining the aperture diameter during adjustment, in direction Z, of the detector unit in the optical head according to the first embodiment of the present invention.

FIG. **16**A is a diagram for explaining an aperture diameter during adjustment of the cylindrical lens in direction X, in a comparative example, FIG. **16**B is a diagram for explaining the aperture diameter during adjustment, in direction X, of the cylindrical lens in the optical head according to the first embodiment of the present invention, and FIG. **16**C is a diagram for explaining the aperture diameter in the optical head according to the first embodiment of the present invention.

FIG. **17** is a diagram illustrating schematically aperture shape in a modification of the optical head according to the first embodiment of the present invention.

FIG. **18** is a diagram illustrating schematically an optical disk drive in an optical information device that uses the optical head according to the first embodiment of the present invention.

FIG. **19**A is a side-view diagram illustrating schematically a detector unit in an optical head according to a second embodiment of the present invention, FIG. **19**B is a front-view diagram illustrating schematically the detector unit, and FIG. **19**C is another side-view diagram illustrating schematically the detector unit.

FIG. **20**A is a side-view diagram illustrating schematically a detector unit in an optical head according to a third embodiment of the present invention, FIG. **20**B is a front-view diagram illustrating schematically the detector unit, FIG. **20**C is another side-view diagram illustrating schematically the detector unit; and FIG. **20**D is a side-view diagram illustrating schematically a modification of the detector unit.

FIG. **21**A is a diagram illustrating schematically an optical system of an optical head in a fourth embodiment of the present invention, and FIG. **21**B is a diagram for explaining a region split in a hologram element provided in the optical system.

FIG. **22**A is a front-view diagram illustrating schematically a light detector provided in the optical head according to the fourth embodiment of the present invention, FIG. **22**B is a diagram for explaining a light-receiving region in the light detector, and FIG. **22**C is a cross-sectional diagram for explaining a relative position relationship between the light detector and an aperture.

FIG. **23**A is a diagram illustrating schematically an optical system of an optical head in a fifth embodiment of the present invention, and FIG. **23**B is a diagram for explaining the orientation, about an axis, of the cylindrical lens provided in the optical system.

FIG. **24**A is a side-view diagram illustrating schematically a detector unit in an optical head according to the fifth embodiment of the present invention, FIG. **24**B is a front-view diagram illustrating schematically the detector unit, and FIG. **24**C is a side-view diagram illustrating schematically the detector unit.

FIG. **25**A is a side-view diagram of a detector unit for explaining bonding positions, between a holder and an optical base, that are provided in an optical head according to a sixth embodiment of the present invention, FIG. **25**B is a front-view diagram of a detector unit showing the bonding positions between the holder and the optical base, and FIG. **25**C is a side-view diagram of a modification of the detector unit.

FIG. **26** is a diagram illustrating schematically an optical system of an optical head according to a seventh embodiment of the present invention.

FIG. **27** is a diagram illustrating schematically the configuration of an optical system in a conventional optical head.

FIG. **28** is a diagram partially illustrating a conventional optical head.

FIG. **29** is a diagram for explaining a light-receiving surface arrangement, and signal extraction, in a light detector of a conventional optical head.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

Embodiments for carrying out the present invention will be explained in detail below with reference to accompanying drawings.

### Embodiment 1

FIG. **1** illustrates schematically an optical system of an optical head **200** according to a first embodiment of the present invention. In FIG. **1**, constituent elements identical to those illustrated in FIG. **27** are explained using the same reference numerals.

As illustrated in FIG. **1**, the optical system of the optical head **200** comprises a semiconductor laser **101** as a light source, a diffraction grating **102**, a beam splitter **103**, a collimator lens **104**, an objective lens **105**, a cylindrical lens **115** and a light detector **120**.

The light beam emitted by the semiconductor laser **101** is split into a plurality of light beams by the diffraction grating **102**. The light beams that pass through the diffraction grating **102** are reflected by the beam splitter **103**, are converted into parallel light beams by the collimator lens **104**, and are incident on the objective lens **105** in the form of so-called three-beam converging light. The converging light is irradiated onto an optical disk **201**. An objective lens actuator **106** drives the objective lens **105** in the optical axis direction (focus direction) and the tracking direction (radial direction) of the optical disk **201**. The light beams reflected and diffracted by an information layer **202** of the optical disk **201** pass again through the objective lens **105**, then through the collimating lens **104**, and are incident on the beam splitter **103**. The light beam that traverse the beam splitter **103** pass through the cylindrical lens **115**, and through an aperture **131** of a holder **130**, and are incident on the light detector **120**.

FIGS. **2**A to **2**C illustrate an example of the light detector **120**. The light detector **120** comprises a light-receiving section **124**, a cover glass **125** and a bonding layer **126**. The light-receiving section **124** comprises a light-receiving surface **121** having a light-receiving region, circuit sections **122** and terminals **123**. The bonding layer **126** bonds the light-receiving section **124** and the cover glass **125**. That is, the light-receiving section **124** is fixed to the cover glass **125**. The terminals **123** are mounted and soldered to an FPC or a board. The terminals **123** output signals in accordance with the quantity of received light as detected by the light-receiving surfaces **121**.

FIG. **3** illustrates schematically a light-receiving surface **121** of the light detector **120**. The light-receiving surface **121** has formed thereon a four-quadrant light-receiving region **140** and sub-beam light-receiving regions **141**. A main beam **142**, from among the light beams that traverse the cylindrical lens **115**, is received by the four-quadrant light-receiving region **140**. The difference between signals at the two pair of diagonally-opposing regions within the four-quadrant light-receiving region **140** (difference between the two sum signals of the diagonally-opposing regions) is computed by a summing amplifier **144** and a differential amplifier **145**, to detect thereby a focus signal. An RF signal is detected through computation, by the summing amplifier **144**, of the sum signals from the respective regions of the four-quadrant light-receiving region **140**.

Sub-beams in the form of reflected light beams that are reflected by a track in the information layer **202** of the optical disk **201**, and that yield a tracking error signal according to a three-beam method, are incident on the sub-beam light-receiving regions **141** of the light detector **120**. Sub-beams **143**, from among the light beams that traverse the cylindrical lens **115**, are received at the sub-beam light-receiving regions **141**.

A summing amplifier **141** and a differential amplifier **142** calculate a signal corresponding to the quantity of received light at the sub-beam light-receiving regions **141** on the basis of a push-pull signal from a signal corresponding to the quantity of received light at the four-quadrant light-receiving region **140**, to generate thereby a tracking error signal in accordance with a three-beam method (so-called DPP method).

FIGS. **4**A to **4**C illustrate the configuration of the cylindrical lens **115**. FIG. **4**B is a front-view diagram of the cylindrical lens **115**. FIG. **4**A is a perspective-view diagram viewed from an incidence surface, and FIG. **4**C is a perspective-view diagram viewed from the exit surface.

The cylindrical lens **115** is shaped overall as a solid cylinder. A cylindrical surface **116** is formed at one end face of the cylindrical lens **115**, in the axial direction, while a concave lens surface **117** having lens power, and a flat surface **128** that surrounds the concave lens surface **117**, are formed at the other end face of the cylindrical lens **115**. The cylindrical lens **115** is disposed in such a manner that the cylindrical surface **116** is an incidence surface for light beams, and the concave lens surface **117** is an exit surface. The flat surface **128** is a surface perpendicular to the lens optical axis **118** of the cylindrical lens **115**, and forms a circular ring that is coaxial with the lens optical axis. In the figure, the reference numeral **119** denotes the central generatrix of the cylindrical surface **116**. The central generatrix coincides with the generatrix that intersects the lens optical axis, from among the generatrices that form the cylindrical surface **116**. The lens optical axis **118** passes through the center of the concave lens surface **117**. The cylindrical surface **116** is positioned furthest inward in the lens optical axis direction, at the position of the central generatrix **119**.

The optical head **200** of the first embodiment comprises a detector unit **127**. The detector unit **127** comprises the cylindrical lens **115**, the holder **130** and the light detector **120**, and is disposed in such a manner that the cylindrical lens **115**, the holder **130** and the light detector **120** are positioned in this order from the side at which the reflected light beam is incident.

Unlike in the case of optical heads where the cylindrical lens is provided spaced apart from the light detector, the optical head **200** of the present embodiment has the holder **130** between the cylindrical lens **115** and the light detector **120**, with both the cylindrical lens **115** and the light detector **120** in contact with the holder **130**. The cylindrical lens **115** is bonded to the holder **130** in such a manner that the cylindrical lens **115** is disposed at one side of the holder **130** in direction Z (optical axis direction of the reflected light beam). The light detector **120** is bonded to the holder **130** in such a manner that the light detector **120** is disposed at the other side of the holder **130** in direction Z.

FIG. **5** illustrates part of the optical head **200**. As illustrated in FIG. **5**, an optical base **113** is provided in the optical head **200**. The optical base **113** holds, for example, the semiconductor laser **101** (FIG. **1**), the diffraction grating **102** (FIG. **1**), the beam splitter **103**, the collimator lens **104** and the objective lens actuator **106** (FIG. **1**). The detector unit **127** is gripped by an external jig (not shown), at holding portions **132** (FIG. **6**A), with respect to the optical base **113**. In that state, the position of the detector unit **127** can be adjusted in direction Z (optical axis direction) along the optical base **113**, and within the X-Y plane (plane perpendicular to the optical axis).

An explanation follows next on a method for adjusting the position of the detector unit **127** with respect to the optical base **113** and the optical axis. Adjustment of the detector unit **127** within the X-Y plane is performed by displacing the detector unit **127** in such a manner that the main beam **142** are incident on substantially the center of the four-quadrant light-receiving region **140**. The position of the detector unit **127** in direction Z is adjusted through fine adjustment of the detector unit **127** in direction Z in such a manner that the light-receiving surface **121** is positioned at an astigmatic-difference focal position, in a state where the positional relationship of the objective lens **105** and the information recording layer **202** is that of just focus. As a result of that fine adjustment, the main beam that is incident on the four-quadrant light-receiving region **140** takes on a circular shape whereby offset in the focus error signal is cancelled. The output of the focus error signal becomes 0 since the objective lens **105** and the information recording layer **202** are now in just focus. The sub-beams **143** are caused to enter substantially the center of the sub-beam light-receiving regions **141** through adjustment (θz) of the reflected light beams about the optical axis. The balance of the focus error signal is adjusted (according to a definition set forth below) through adjustment in direction X and direction Y, offset of the tracking error signal is adjusted through rotation adjustment (θz), and focus offset of the focus error signal is adjusted through adjustment in direction Z. The position of the detector unit **127** is thus adjusted in direction Z and directions X-Y as described above. In the optical head **200** of the present embodiment, however, the cylindrical lens and the light detector **120** are both fixed to the holder **130**, and hence the relative positional offset of the cylindrical lens **115** and the light detector **120** can be reduced vis-à-vis that in conventional optical heads.

FIGS. **6**A to **6**C illustrate the configuration of the detector unit **127**. FIG. **6**A is a side-view diagram viewed from the light detector, FIG. **6**C is a side-view diagram viewed from the cylindrical lens, and FIG. **6**B is a front-view diagram.

The holder **130** is formed as a flat plate having a constant thickness. The holder **130** comprises, for example, a tubular aperture **131**, holding portions **132**, a light detector pressing section **137**, light detector positioning sections **135**, a cylindrical lens pressing section **138** and cylindrical lens positioning sections **136**. The cylindrical lens **115** is bonded to the face of the holder **130** at the side on which light reflected by the optical disk is incident. The light detector **120** is bonded to the holder **130** at the face on the opposite side thereto. One of the main faces of the holder **130** at which the cylindrical lens **115** is bonded (one end face in the optical axis direction of the reflected light beam) may also be referred to as a first main face, and the other main face of the holder **130** at which the light detector **120** is bonded may also be referred to as second main face. The first main face and second main face are set to be parallel to each other.

The light detector pressing section **137** is a section formed on the second main face of the holder **130**, and is positioned at substantially the center of the second main face. Specifically, part of the second main face functions as the light detector pressing section **137**. The light detector **120** is in face contact with the light detector pressing section **137**. With the light detector positioning sections **135** being provided on the second main face, the light detector **120** can be positioned in direction X and direction Y in use of this the light detector positioning sections **135**.

The cylindrical lens pressing section **138** is formed on the first main face of the holder **130**, at a position substantially in the center of the first main face. Specifically, part of the first main face functions as the cylindrical lens pressing section **138**. The flat surface **128** of the cylindrical lens **115** is in face contact with the cylindrical lens pressing section **138**. The cylindrical lens positioning sections **136**, which are provided on the first main face, have a circular arc surface that is formed concentrically with the aperture **131**. This circular arc surface opposes the peripheral face of the cylindrical lens **115**. The cylindrical lens positioning sections **136** are used to allow positioning the cylindrical lens **115** in direction X and direction Y, and to allow the cylindrical lens **115** to rotate smoothly about the optical axis during adjustment of the orientation of the cylindrical lens **115** in the peripheral direction.

The aperture **131** is formed within the area of the light detector pressing section **137** and the cylindrical lens pressing section **138**, as viewed in the optical axis direction. The aperture **131** is an opening, having a circular cross-section, that runs through the holder **130** in the thickness direction thereof.

The thickness of the holder **130** is controlled so as to be constant. As a result, the gap between the light detector **120** and the cylindrical lens **115** can be defined with good precision, and the orientation of the cylindrical lens **115** can be matched, with good precision as well, to the optical axis direction of the reflected light beam. The thickness of the holder **130** is, for instance, about 1.5 mm.

To position the light detector **120**, the holding portions **132** of the holder **130** are gripped by an external jig (not shown), and in that state, the light detector **120** is pressed against the light detector pressing section **137**, to position thereby the light detector **120** by way of the light detector positioning sections **135**. The light detector **120** is positioned as a result, with good precision, in direction X, direction Y and direction Z, with respect to the holder **130**. In that state, the light detector **120** is bonded and fixed by way of light detector bonding sections **133**.

In the above configuration, unlike optical heads in which the light detector and the cylindrical lens are built separately, the positional error of the cylindrical lens **115** and the light detector **120** in direction Z is given by the dimensional error of the holder **130** alone. This dimensional error is determined by the precision of the holder **130** as a component, in terms of molding precision and machining precision. The dimensional error can therefore be kept low, between about 5 and 20 μm. In a rough approximation, as described below, the positional offset between a light detector and a cylindrical lens in conventional optical heads is of about 300μ. The configuration in the present embodiment allows thus reducing such positional offset significantly. A smaller positional offset of the beam of light that strikes the light detector **120** allows in turn preventing impairment of the characteristics of the recording and reproduction signals.

The cylindrical lens **115** is positioned in direction X and direction Y by way of the cylindrical lens positioning sections **136**. The cylindrical lens **115** is positioned in direction Z through pressing of the flat surface **128** of the cylindrical lens **115** against the cylindrical lens pressing section **138**. The cylindrical lens **115** is disposed in such a manner that the incidence surface side thereof becomes the cylindrical surface **116**. As a result, the orientation of the central generatrix **119** of the cylindrical surface **116** can be checked easily and with high precision by causing parallel light beams to strike the cylindrical surface **116**, using an auto-collimator or the like, not shown, and checking then the shape of the reflected light beam (central generatrix **119** of the cylindrical surface **116**). Specifically, the rotation direction of the cylindrical lens **115** may be adjusted by detecting the angle of the cylindrical surface **116** (orientation of the central generatrix **119** of the cylindrical surface **116**), using an external measurement device (not shown) such as an auto-collimator or the like. The cylindrical lens **115** may then be bonded and fixed to the holder **130** by way of the cylindrical lens bonding sections **134**. The light detector **120** and the cylindrical lens **115** can be positioned thereby, with greater precision, with respect to the holder **130** and the aperture **131**.

In the optical system of the present embodiment, the cylindrical surface **116** of the cylindrical lens **115** is positioned at the incidence side of the light beam reflected from the optical information medium. The cylindrical lens is not supposed to be at a close distance from the light detector in optical heads of detection optical systems of low magnification, and hence the cylindrical surface **116** is disposed on the side of the light detector. In the present embodiment, by contrast, the cylindrical lens **115** and the detector **120** are disposed so as to sandwich the holder **130** therebetween. Therefore, the distance between the cylindrical surface **116** and the light-receiving surface of the light detector **120** is smaller when the cylindrical lens surface **116** is disposed on the side of the light detector **120**. The focus error signal performance may become impaired as a result. In the present embodiment, therefore, the cylindrical lens **115** is disposed in such a manner that the cylindrical surface **116** stands on the side of the light incidence surface. The above configuration allows increasing the astigmatic difference also when the magnification of the detection optical system is large.

As a result, the distance between the front focal line and the focal position and the distance between the rear focal line and the focal position can be made greater, with better balance. Focus error signals having good symmetry can be realized thereby, and also the quality of the focus servo can be enhanced. FIG. **7** illustrates a front focal line, a focal position and a rear focal line.

The holder **130** is in contact with the flat surface **128** of the cylindrical lens **115** upon adjustment of the orientation of the central generatrix **119** of the cylindrical surface **116** in the peripheral direction. The abutting surface area between the cylindrical lens **115** and the holder **130** is accordingly large. As a result, rotation of the central generatrix **119** of the cylindrical surface **116** about the lens optical axis **118** can be adjusted once the relative angle between the cylindrical lens **115** and the holder **130** is stabilized. As used herein, the term rotation adjustment denotes adjustment of the orientation of the central generatrix **119** of the cylindrical surface **116** with respect to direction of the parting lines of the four-quadrant light-receiving region **140**. For instance, the angles of the front focal line and rear focal line with respect to the orientation of the parting line of the four-quadrant light-receiving region **140** are adjusted to 45°, as illustrated in FIG. **10**. The flat portion **128** and the holder **130** are in close contact with each other, and are bonded and fixed in that state. Reliability can be significantly enhanced thereby.

FIG. **8** illustrates the configuration of the cylindrical surface **116** of the cylindrical lens **155** disposed on the side of the light detector **120**, for comparison vis-à-vis the configuration in FIG. **7**. FIGS. **9**A and **9**B illustrate the relationship between the position of the front focal line, the position of the rear focal line and the position of the cylindrical surface **116** with respect to the focal position on the light detector **120** of FIG. **7** and FIG. **8**. FIG. **9**A illustrates a configuration, corresponding to FIG. **7**, in which the cylindrical surface **116** and the focal position (light-receiving surface of the light detector **120**) are spaced apart from each other. FIG. **9**B illustrates a configuration, corresponding to FIG. **8**, in which the cylindrical surface **116** is close to the focal position.

In FIGS. **9**A and **9**B, the ratio of the distance between the focal position and the front focal line and the distance between the focal position and the rear focal line is 0.8:1 in a configuration in which the cylindrical surface **116** is disposed at the opposite side away from the light detector **120** (FIG. **9**A), assuming a spot diameter (circle of least confusion) of the focal position of 1 mm. In the present embodiment there can be obtained a stable so-called focus error signal wherein an S-shaped signal exhibits good symmetry with respect to GND, despite the small size of the optical head (FIG. **9**C).

By contrast, the ratio of the distance between the focal position and the front focal line and the distance between the focal position and the rear focal line is 1:3 in a configuration in which the cylindrical surface **116** is disposed on the side of the light detector **120** (FIG. **9**B). In this case, the resulting focus error signal is an S-shaped signal having significantly worse symmetry with respect to GND (FIG. **9**D). This translates into unstable focus servo. The astigmatic difference distance is about 20 to 30% greater in the configuration of FIG. **9**B, where the cylindrical surface **116** is disposed on the side of the light detector **120**, than the configuration of FIG. **9**A, in which the cylindrical surface **116** is disposed at the opposite side away from the light detector **120**. An S-shaped signal (focus error signal) securing a wide acquisition range can be achieved as a result in the configuration of FIG. **9**A, which allows realizing stable focus servo.

In the configuration of the present embodiment, the flat surface **128** of the cylindrical lens **115** and the holder **130** are fixed by being bonded to each other while in a closely attached state in the detector unit **127** that comprises the cylindrical lens **115**, the holder **130** and the light detector **120** integrally formed with each other. The foregoing are bonded to each other by way of the cylindrical lens bonding sections **134** where the cylindrical lens pressing section **138** and the flat surface **128** are in a closely attached state. This results in a small relative positional offset and relative angle offset between the cylindrical lens **115** and the holder **130**, that are caused by adhesive swelling or shrinkage. The quality of the focus error signal can be made more stable as a result. The cylindrical surface **116**, moreover, is disposed on the side of the incidence surface. The rotation of the cylindrical lens **115** can be adjusted therefore quickly and with high precision. An optical head **200** of superior performance can be realized as a result.

When the cylindrical surface **116** and the concave lens surface **117** are compared with each other, for a lens surface having a same given curvature, the cylindrical surface **116** is more difficult to form than the concave lens surface **117**, in terms of molding and lens formation. The relative distance between the light-receiving surface **121** of the detector **120** and the cylindrical surface **116** can be lengthened by arranging the cylindrical surface **116** at the side of the incidence surface. Doing so allows reducing comparatively the lens power of the cylindrical surface **116**, and makes molding and forming of the cylindrical surface **116** easier.

The characteristics of the surface of the holder **130** that abuts the light detector **120** will be explained briefly next. A characterizing feature of the present embodiment is the lower coefficient of friction within a predetermined area of the light detector pressing section **137**, as the abutting surface that abuts the light detector **120** within the surface of the holder **130**. This facilitates position adjustment of the light detector **120**. Specifically, the surface roughness of the mold for forming the holder **130**, at a portion corresponding to the predetermined area of the light detector pressing section **137**, is smaller than the surface roughness of other portions. The surface at this portion is thus smoother. In the present embodiment, the light detector **120** is pressed against the light detector pressing section **137** of the holder **130**, with the holding portions **132** of the holder **130** gripped by an external jig (not shown). The position of the light detector **120** within the X-Y plane is then adjusted in this state. The position of the light detector **120** can be adjusted precisely, with small displacements of 1 micron or less, by reducing the coefficient of friction of the surface that abuts the light detector **120**, within the surface of the holder **130**. Reducing the coefficient of friction to a greater degree at the portion that comes into contact with the light detector **120** is also advantageous in that the holder **130** can be formed thereby at a lower cost than in the case where the coefficient of friction is reduced all over the light detector pressing section **137** (also referred to as second main face). Herein, the surface that abuts the light detector **120** is highly likely to be a region that encompasses the central portion of the light detector pressing section of the holder **130** (also referred to as second main face), i.e. that encompasses the barycenter position. That is, reducing the surface roughness of a region that encompasses the barycenter allows eliciting the envisaged effect of enabling adjusting smoothly at least the flat surface.

Also, the coefficient of friction within a predetermined area of the cylindrical lens pressing section **138**, which is the surface that abuts the cylindrical lens **115** within the surface of the holder **130**, is reduced. This facilitates adjusting the position of the cylindrical lens **115**. In the present embodiment, the cylindrical lens **115** is pressed against the cylindrical lens pressing section **138** of the holder **130**, with the holding portions **132** of the holder **130** gripped by an external jig (not shown). The position of the cylindrical lens **115** within the X-Y plane is then adjusted in this state. The position of the cylindrical lens **115** can be adjusted precisely, with small displacements of 1 micron or less, by reducing the coefficient of friction of the surface that abuts the cylindrical lens **115**, from within the surface of the holder **130**. Reducing the coefficient of friction to a greater degree at the portion that comes into contact with the cylindrical lens **115** is also advantageous in that the holder **130** can be formed thereby at a lower cost than in the case where the coefficient of friction is reduced all over the cylindrical lens pressing section **138** (also referred to as first main face). Herein, the surface that abuts the cylindrical lens **115** is highly likely to be a region that encompasses the central portion of the cylindrical lens pressing section of the holder **130** (also referred to as first main face), i.e. that encompasses the barycenter position. That is, reducing the surface roughness of a region that encompasses the barycenter allows eliciting the envisaged effect of enabling adjusting smoothly at least the flat surface.

The surface roughness of the circular arc surface of the cylindrical lens positioning sections **136** may be set to be approximately the surface roughness of the cylindrical lens pressing section **138**.

Conventional light detectors do not have to be positioned in a state where the light detector is abutting the holder. In the present embodiment, by contrast, positioning of the light detector **120** is adjusted in a state where the light detector **120** is abutting the holder **130**. As a result, more precise positioning can be achieved by reducing the coefficient of friction of the holder surface vis-à-vis the coefficient of friction of the surrounding surface, at a predetermined area (for instance, at the region at which the holder **130** and the light detector **120** come into contact, and at a 300 micron area that constitutes a position adjustment area on the second main face) within the light detector pressing section **137** of the holder **130**. In the present embodiment, the positioning of the cylindrical lens **115** is adjusted in a state where the cylindrical lens **115** is abutting the holder **130**. As a result, more precise positioning can be achieved by reducing the coefficient of friction of the holder surface vis-à-vis the coefficient of friction of the surrounding surface, at a predetermined area (for instance, at the region at which the holder **130** and the cylindrical lens **115** come into contact, and at a 300 micron area that constitutes a position adjustment area on the first main face) within the cylindrical lens pressing section **138** of the holder **130**.

In the present embodiment, at least part (light detector pressing section **137**) of the second main face has a smaller surface roughness than the surface roughness at other portions. However, the embodiment is not limited thereto. For instance, the surface roughness over the entire second main face may be smaller than the surface roughness of a side face (face parallel to the optical axis) of the holder **130**. In the present embodiment, at least part (cylindrical lens pressing section **138**) of the first main face has a smaller surface roughness than the surface roughness at other portions. However, the embodiment is not limited thereto. For instance, the surface roughness over the entire first main face may be smaller than the surface roughness of a side face (face parallel to the optical axis) of the holder **130**.

FIG. **11** illustrates a method for fixing the detector unit **127** to the optical base **113**.

After adjusting the position of the detector unit **127** in direction X, direction Y and direction Z, and the rotation of the detector unit **127** about the optical axis, an adhesive is coated onto the holder bonding sections **139**, which are the bonding sections between the optical base **113** and the holder **130**, and the detector unit **127** is fixed to the optical base **113**.

In order to realize a small optical head that supports also recording and reproduction to/from multilayer optical disks, the detection optical system, which has the objective lens **105**, the collimating lens **104** and the light detector **120**, is required to have a greater lateral magnification, is required to be configured in such a manner that stray light reflected from other layers does not enter the sub-beam light-receiving regions, and is required to be small in size. Tracking error signal offset occurs when stray light reflected by other layers is incident on the sub-beam light-receiving regions. Tracking servo performance is significantly impaired thereby, which results in a loss of recording and reproduction performance.

It becomes necessary therefore to increase the size of the detection optical system of the optical head. On the other hand, large lens power is required to be achieved, by forming a lens surface having a small radius of curvature on the cylindrical lens, in order to reduce the size of the detection optical system.

FIG. **12**A illustrates the relationship between the magnification (lateral magnification β) of the detection optical system and the radius of the concave lens portion (concave lens surface) of the cylindrical lens, and the approximate calculated value of sub-beam offset with respect to the main beam on the light detector. As used herein, the term detection optical system refers to the optical system along the path that a reflected light beam follows from the objective lens **105** up to the light detector **120**, and that comprises the objective lens **105**, the collimating lens **104** and the cylindrical lens **115**. The lateral magnification denotes the ratio of focal length of the optical system that combines the collimating lens **104** and the cylindrical lens **115**, with respect to the focal length of the objective lens **105**. Sub-beam offset with respect to the main beam on the light detector **120** occurs on account of errors in the distance between the cylindrical lens **115** and the light detector **120**.

In a case where the cylindrical lens and the light detector are configured spaced apart from each other, the offset of the distance between the cylindrical lens and the light detector is at most of about 300 μm, even after adjustment in the optical axis direction. FIG. **12**A tabulates the results of a calculation of sub-beam spot positional offset for an offset of about 100 μm of the distance between the cylindrical lens and the light detector.

For an optical head of a given size, the radius of the concave lens portion decreases sharply accompanying greater magnification when, with a view to cope with multilayer optical disks, the magnification (lateral magnification) of the detection optical system exceeds 10 times, instead of 5 times to 10 times, as in conventional cases. The detection optical system becomes as a result more sensitive to positional offset between the cylindrical lens and the light detector, in the optical axis direction, and there increases sub-beam offset with respect to the main beam.

Conversion of sub-beam positional offset to PD balance is considered next. It is deemed that, ordinarily, tracking servo characteristics become significantly impaired for a 30% offset in PD balance, which exerts a non-negligible influence on reproduction and recording signal characteristics.

The definition of PD balance is explained next with reference to FIG. **12**B, FIG. **7** and FIG. **10**.

FIG. **7** is a diagram illustrating the relationship between the central generatrix **119** of the cylindrical surface of the cylindrical lens **115** and the four-quadrant light-receiving region **140**. The cylindrical lens **115** gives rise to an astigmatic difference between mutually dissimilar focal positions. The astigmatic difference arises between the front focal line and the rear focal line that are at an angle of 90 degrees with respect to each other within the X-Y plane (within the plane perpendicular to the optical axis of the reflected light beam). The central generatrix **119** of the cylindrical surface in FIG. **7**, which is set along a direction perpendicular to the paper, is disposed at an oblique angle of 45 degrees with respect to the parting lines of the four-quadrant light-receiving region **140** of the light detector **120** (FIG. **10**).

The relative distance between the information layer **202** and the objective lens **105** varies due to, for instance, surface runout of the optical disk **201**. Light is focused as a result at the front focal line and the rear focal line. The light-receiving surface **121** is disposed at the focal position in the figure. The magnification (lateral magnification β) of the detection optical system is determined by the focal length of the objective lens **105**, the focal length of the collimating lens **104** and the optical power of the concave lens surface **117** of the cylindrical lens **115**.

FIG. **10** illustrates the shape of the front focal line and rear focal line viewed from the optical axis direction, and the shape of a light beam on the four-quadrant light-receiving region **140**. The focus error signal is calculated as (A+C)−(B+D), the PD balance (direction X) as ((A+B)−(C+D))/(A+B+C+D), and the PD balance (direction Y) as ((A+D)−(B+C))/(A+B+C+D), wherein A, B, C and D denote detection signals of respective light-receiving regions in the four-quadrant light-receiving region **140**.

The position of the detector unit **127** is adjusted in direction X and direction Y in such a manner that PD balance (direction X) and PD balance (direction Y) approach 0.

Herein, a 1 μm sub-beam offset on the light detector corresponds to an offset of about 5% for sub-beam PD balance. Therefore, the sub-beam PD balance exhibits an offset of about 20% in a detection optical system where magnification is 16 times. The PD balance exhibits an offset of about 60% in a case where the distance between the cylindrical lens and the light detector is offset by 300 μm. Thus, an increase in the tracking error signal offset translates into a significant impairment of tracking servo performance.

It is therefore difficult to adjust the cylindrical lens and light detector separately in optical heads that are small and that comprise a high-magnification detection optical system.

In the present embodiment, by contrast, the positional offset of the cylindrical lens **115** and the light detector **120** in the Z axial direction can be reduced to be of about 5 μm up to 20 μm. Therefore, the PD balance is of about 4%, even in cases where a lens having 16 times detection magnification is used. This PD balance value is very low, as compared with that of conventional optical heads, and indicates that good reproduction signal characteristics can be preserved even when using an objective lens having high detection magnification. The lateral magnification in the first embodiment ranges preferably from 14 times to 16 times. The radius of curvature of the cylindrical surface may be equal to or smaller than 2.6 mm in the case of 14 times lateral magnification.

FIG. **13**A illustrates schematically an instance of surface reflection from another recording layer in a two-layer optical disk **201**. FIG. **13**B illustrates schematically an instance of surface reflection from another recording layer in a multilayer optical disk **301**. Reflected light from these other layers is incident on the sub-beam light-receiving regions **141** and introduces offset in the tracking error signal, impairing as a result the quality of tracking servo. FIG. **13**A illustrates an instance of stray light from another recording layer when converging light **300** is focused on a given recording layer in a case where the optical disk **201** is a two-layer disk. Upon focusing onto layer L0 (recording layer), light reflected by layer L1 (recording layer) becomes other-layer stray light.

FIG. **13**B illustrates an instance of stray light from another recording layer when converging light **300** is focused on a given recording layer in a case where the optical disk **301** is a four-layer disk. In FIG. **13**B, light is focused onto layer L2 (recording layer), and light reflected by layer L0, layer L1 and layer L3 (recording layer) becomes other-layer stray light. The standard spacing d**2** between layer L0 and layer L1 in the case of the two-layer disk illustrated in FIG. **13**A is 25±5 μm, i.e. minimum 20 μm and maximum 30 μm. As a result, the amount of other-layer stray light on the light detector **120** can be limited to certain extent. In the case of an optical disk having three or more layers, for instance the four-layer disk illustrated in FIG. **13**B, it is very likely that the layer spacing d**4**min, which is the smallest layer spacing (in the figure, for instance, layer spacing between layer L2 and layer L3) is smaller than that in the case of a two-layer optical disk. For the layer spacing d4max between the layers that are most spaced apart from each other (in the example of the figure, the layer spacing between layer L0 and layer L3), the amount of other-layer stray light that is incident on the light detector **120** is significantly greater than that in the case of a two-layer optical disk. Therefore, in order to detect a stable tracking error signal, and support recording and reproduction to/from multilayer optical disks, it is necessary to increase the magnification (lateral magnification β) of the detection optical system in such a manner that other-layer stray light does not leak onto the sub-beam light-receiving regions **141**, and it is necessary to widen the distance between the four-quadrant light-receiving region **140** that receives the main beam **142** and the sub-beam light-receiving regions **141** that receive the sub-beams **143**.

FIGS. **14**A and **14**B illustrate the relationship between the size of other-layer stray light **147** and the distance between the sub-beams **143** and the main beam **142** on the light detector **120**. The distance between the main beam **142** and the sub-beams **143** on the light detector **120** is a value resulting from multiplying the gap between the sub-beams and the main beam, which is condensed onto the information recording layer **202** (FIG. **1**), by the lateral magnification of the detection optical system. For instance, the distance between the main beam **142** and the sub-beams **143** on the light detector **120** is of about 120 μm when a gap between the main beam and the sub-beams on a track of the information recording layer **202** is 20 μm and the lateral magnification of the detection optical system is about 6 times. To detect stable tracking error signals in order to support recording and reproduction to/from multilayer optical disks, however, the size of other-layer stray light is required to be about 150 μm, and the lateral magnification of the detection optical system about 10 times. The distance between the main beam **142** and the sub-beams **143** is about 200 μm in this case. The spacing between the main beam and the sub-beams on the track of the information layer **202** is about 20 μm. This value, which affects the tracking error offset upon movement from the inner periphery towards the outer periphery of the optical disk **201**, is set beforehand in each device. The selected value ranges ordinarily from 10 μm to 20 μm.

The dimensions of the detection optical system are required to be reduced in order to realize a smaller optical head **200**. The detection optical system is required to also be made smaller, with the influence of the other-layer stray light in mind. The influence of other-layer stray light mandates a greater magnification in the detection optical system. For a given lateral magnification, however, the focal length of the objective lens **105** becomes smaller when the size of the detection optical system is reduced only at the objective lens **105** and the collimating lens **104**. The working distance between the objective lens **105** and the surface of the optical disk **201** becomes shorter as a result. Therefore, reducing the size of the detection optical system is difficult to realize on account of the problem of focus servo difficulties that doing so entails. However, lateral magnification can be increased without modifying the focal length of the objective lens **105**, and the dimensions of the detection optical system can be made smaller, by arranging the concave lens surface **117** on the side of the exit surface of the cylindrical lens **115**, as described above.

In order to increase the distance between the four-quadrant light-receiving region **140** and the sub-beam light-receiving regions **141**, the lateral magnification of the detection optical system comprising the objective lens **105**, the collimating lens **104**, and the concave lens **117** of the cylindrical lens **115**, is preferably set to range from about 10 times to 20 times.

With increased lateral magnification, the dimensions of detection optical system is required to then be reduced in order to realize a small optical head **200**. A lens having a very large lens power, with a radius of curvature of about 5 mm to 1 mm (equal to or greater than 1 mm and equal to or smaller than 5 mm) is required to be used as the concave lens **117** of the cylindrical lens **115**.

The lateral magnification of the detection optical system varies greatly, on account of the relative distance error between the cylindrical lens **115** and the light-receiving surface **121** of the light detector **120**, in a configuration where the magnification in the detection optical system is increased and the cylindrical lens **115** has a substantial lens effect. Accordingly, there increases the likelihood that the sub-beams **143** necessary for generating the tracking error signal are incident at positions off the sub-beam light-receiving regions **141**. For instance, the lateral magnification of the detection optical system is reduced, and the sub-beams **143** are incident on nearer the four-quadrant light-receiving region **140**, when the distance between the cylindrical lens **115** and the light detector **120** is shorter than a predetermined distance. Conversely, the lateral magnification of the detection optical system increases, and the sub-beams **143** strike outside the sub-beam light-receiving regions **141**, when the distance between the cylindrical lens **115** and the light detector **120** is longer than a predetermined distance.

In a detection optical system having a lateral magnification equal to or greater than 10 times, the change in lateral magnification is equal to or greater than about 0.7% when the relative distance error between the cylindrical lens **115** and the light detector **120** exceeds 50 μm. That is, the sub-beams **143** shift by several μm in direction Y, and the change in tracking error signal offset exceeds about 10%. Tracking servo performance becomes significantly impaired as a result. In a detection optical system having large lateral magnification, therefore, it is necessary to reduce the relative distance error between the cylindrical lens **115** and the light detector **120** to be significantly smaller than 50 μm.

In the optical head **200** of the present embodiment, the light detector **120** and the cylindrical lens **115** can be positioned beforehand on the holder **130**, with good precision, upon adjustment of the position of the detector unit **127**. Therefore, the relative position error between the cylindrical lens **115** and the light detector **120** with respect to the holder **130** can be reduced significantly upon adjustment of the position of the light detector **120** within the X-Y plane, on the optical base **113**, and upon adjustment of the position of the cylindrical lens **115** in direction Z (optical axis direction). Error in the lateral magnification of the detection optical system and deterioration of the tracking error signal can both the significantly reduced as a result.

In the optical head **200** of the present embodiment the cylindrical lens **115** and the light detector **120** are integrated together, and hence the positional error of the cylindrical lens **115** with respect to the light detector **120** in direction Z arises only from dimensional errors in the holder **130**. This dimensional error can be kept within a range of 5 to 20 μm, and hence the positional error between the cylindrical lens **115** and the light detector **120** in direction Z can be reduced to be no greater than 50 μm. The relative positional error of the cylindrical lens **115** with respect to the light detector **120** in direction X and direction Y can also be kept no greater than 50 μm. As a result, it becomes thus possible to use an optical head

**200** having large lateral magnification, and to realize a small high-performance optical head **200**, also for a multilayer optical disk **301**.

The cylindrical lens **115** and the light detector **120** are fixed beforehand to the holder **130** in the detector unit **127**. As a result, the position of the detector unit **127** itself can be adjusted within the X-Y plane, on the optical base **113**, and can be adjusted also in the optical axis direction (direction Z). Changes in the lateral magnification of the detection optical system can be reduced thereby. As a result there can be realized an optical head **200** having excellent reliability and that can perform stable recording and reproduction with little offset fluctuation in tracking error signal.

FIGS. **15**A and **15**B illustrate the influence of the diameter of the aperture **131** during adjustment in direction Z. Also in a configuration where the aperture **131**, the cylindrical lens **115** and the light detector **120** are integrated together, a wider opening diameter of the aperture **131** is preferable on account of the associated greater error tolerance during adjustment of the aperture **131**, the cylindrical lens **115** and the light detector **120**. A detection optical system having a magnification equal to or greater than 10 times is used in order to enable recording and reproduction to/from the multilayer optical disk **301** when integrating the aperture **131**, the cylindrical lens **115** and the light detector **120**, as in the present embodiment. During recording and reproduction in such a multilayer optical disk **301**, reflected light (other-layer stray light) from information recording layers other than the target layer for recording or reproduction is also incident, which affects significantly the quality of the reproduction signal. This multilayer stray light is required to be therefore cut off. Such being the case, the surface area of the aperture **131** is required to be made smaller.

The adjustment amount of the light detector **120** cannot be prevented from introducing an error in the relative position between the aperture **131** and the cylindrical lens **115** in an optical head where the cylindrical lens **115** is spaced apart from the aperture **131** and the light detector **120** but where the aperture **131** and the light detector **120** are integrated together. Therefore, at least a dimensional allowance is required in the opening diameter, the allowance being equal to or greater than the adjustment amount (ordinarily, from about 0.05 mm to 1 mm) within a plane perpendicular to the optical axis of the light detector **120**. In the present embodiment, by contrast, the aperture **131**, the cylindrical lens **115** and the light detector **120** are all integrated together, and hence the opening diameter of the aperture **131** can be made smaller.

FIG. **15**A illustrates an optical head in a comparative example. In this case, the relative position between the holder **130** and the cylindrical lens **115** varies through adjustment of the cylindrical lens **115** in the front-rear direction (direction Z). Therefore, the diameter of a light beam passing through the aperture **131** varies significantly between a main beam a and a main beam b. The diameter of the aperture **131** is required to be increased as a result, which is accompanied by a significant increase in the amount of stray light that strikes the sub-beam light-receiving regions **141** of the light detector **120**.

In the optical head **200** of the present embodiment illustrated in FIG. **15**B, by contrast, the detector unit **127** is integrally adjusted in direction Z. Therefore, the relative distance between the cylindrical lens **115** and the holder **130** does not change, and hence the diameter of the light beams that pass through the aperture **131** remains virtually unchanged. The diameter of the aperture **131** can be therefore reduced to the utmost, and the amount of stray light striking the sub-beam light-receiving regions **141** of the light detector **120** can be reduced significantly.

The difference in the diameter of the aperture **131** during adjustment in direction X will be explained next with reference to FIGS. **16**A and **16**B. FIG. **16**A illustrates an optical head in a comparative example. In this optical head, the relative position relationship between the cylindrical lens **115** and the holder **130** is modified by adjusting the light detector **120** to the left and right (direction X). Therefore, the diameter of a light beam passing through the aperture **131** varies significantly between a main beam a and a main beam b. The diameter of the aperture **131** is required to be increased as a result, which is accompanied by a significant increase in the amount of stray light that strikes the sub-beam light-receiving regions **141** of the light detector **120**.

In the optical head **200** of the present embodiment illustrated in FIG. **16**B, by contrast, the detector unit **127** moves as a single body in direction X. Accordingly, the relative distance between the cylindrical lens **115** and the holder **130** does not change, and thus the diameter of the light beam that passes through the aperture **131** remains virtually unchanged. The diameter of the aperture **131** can be therefore reduced to the utmost, and the amount of stray light striking the sub-beam light-receiving regions **141** of the light detector **120** can be reduced significantly.

An explanation follows next, with reference to FIG. **16**C on the relationship between the dimensions of the aperture **131** with respect to the dimensions of the main beam a in the optical head of the present embodiment.

The aperture diameter can be equated to the sum of the diameter of the reflected light beam, the positional offset amount, in direction X (or direction Y), of the cylindrical lens **115** with respect to the aperture **131** of the holder **130**, the positional offset amount, in direction X (or direction Y), of the light detector **120** with respect to the aperture **131** of the holder **130**, and the increase in the reflected light beam diameter at the position of the aperture **131** that results from adjusting the position of the light detector unit **127** in direction Z. That is, the adjustment dimensions (about 0.05 mm to 1 mm) of the light detector unit **127** in direction X (or direction Y) can be excluded, and hence the aperture diameter can be reduced significantly.

In the present example, the aperture **131** is shaped as a cylindrical hole, but may also be shaped as a conical hole, as illustrated in FIG. **17**. Such a configuration allows further reducing the aperture diameter in conceivable cases where sub-beams **143** strike obliquely.

Needless to say, the emission wavelength of the semiconductor laser **1**, as the light source in the first embodiment, may suitable be of about 780 nm for CDs, of about 650 nm for DVDs, or of about 405 nm for BDs.

FIG. **18** illustrates an example of the configuration of an optical disk drive **400** as an optical information device where the above optical head **200** is used. The optical disk **201** is fixed between a clamper **401** and a turntable **402**, and is caused to rotate in that state by a motor (rotation system) **403**. The optical head **200** rests on a traverse (transport system) **404**, such that the point struck by light can shift from the inner periphery of the optical disk **201** towards the outer periphery thereof. On the basis of signals received from the optical head **200**, the control circuit **405** performs, for instance, focus control, tracking control, traverse control as well as control of the rotation of the motor **403**. A signal processing circuit **406** reproduces information on the basis of a reproduction signal, and outputs the result to an input/output circuit **407**. The signal processing circuit **406** also sends signals coming from the input/output circuit **407** to the optical head **200**, via the control circuit **405**.

The present embodiment affords a more distinctive effect through the use of an optical head **200** having a cylindrical lens **115** of high concave lens power, and having a large-magnification detection optical system. The cylindrical surface **116** of the cylindrical lens **115** is disposed at the opposite side away from the light detector **120**. The servo signal performance can be further enhanced thereby. The present invention, however, can be used irrespective of the magnitude of the lens power of the cylindrical lens, and can be used in other optical heads, without restrictions. In those cases as well, the present invention allows reducing the relative positional error between a cylindrical lens and a light detector.

The cylindrical lens **115** in the present embodiment is made up of a glass material, and is bonded to the holder **130** that is made up of a metal such as zinc, aluminum or the like. However, the cylindrical lens **115** and the holder **130** may both be made up of a resin. Also, the cylindrical lens **115** and the holder **130** may be made up of resin and be formed integrally with each other.

## Embodiment 2

An optical head according to a second embodiment of the present invention will be explained next.

FIGS. **19**A to **19**C illustrate the detector unit **127** provided in the second embodiment and illustrate the relationship between the light detector **120**, the cylindrical lens **115**, the holder **130** and the aperture **131**.

The detector unit **127** of the present embodiment lacks the light detector positioning sections **135** and the cylindrical lens positioning sections **136**. The holder **130** of the detector unit **127** has the aperture **131**, the holding portions **132**, the light detector pressing section **137**, the cylindrical lens pressing section **138**, the light detector bonding sections **133** and the cylindrical lens bonding sections **134**. In the detector unit **127** there is adjusted the relative position relationship between the aperture **131** and the light detector **120**, as well as the relative position relationship between the aperture **131** and the cylindrical lens **115**. In the above adjustments, the position of the light-receiving surface **121** of the light detector **120** is adjusted, in direction X and direction Y, with respect to the aperture **131** and the holding portions **132** of the holder **130**, in the X-Y plane, and also the angle θz about the optical axis is adjusted. The holder **130** is fixed thereafter. The light detector **120** can be positioned thereby, with good precision, with respect to the holder **130**.

The position of the cylindrical lens **115** is adjusted with respect to the holder **130** or the aperture **131**, in such a manner that the outer shape of the cylindrical lens **115** or the lens optical axis **118** of the cylindrical lens **115** coincides with the center of the aperture **131**. The position is adjusted by adjusting the position in direction X and direction Y within the X-Y plane. The angle θz of the cylindrical lens **115** about the optical axis is also adjusted. This is done by rotating the cylindrical lens **115** about the optical axis in such a manner that the central generatrix **119** of the cylindrical surface **116** adopts a predetermined orientation.

In the detector unit **127**, the above configuration allows positioning and fixing, with good precision, the cylindrical lens **115**, the aperture **131** and the light-receiving surface **121** of the light detector **120**. The inner diameter of the aperture **131** can be reduced thereby to the essential minimum. Other-layer stray light coming from the multilayer recording medium and that strikes the light-receiving surface **121** of the light detector **120** can be better blocked as a result. Also, the optical head **200** can be made thinner, since the shape of the holder **130** can be made smaller.

In the present embodiment, the position of the cylindrical lens **115** in the Z axial direction is adjusted by pressing the cylindrical lens **115** against the cylindrical lens pressing section **138**, after which the cylindrical lens **115** is bonded and fixed to the holder **130** at the cylindrical lens bonding sections **134**. The embodiment, however, is not limited thereto, and the position of the cylindrical lens **115** in the Z axial direction may be adjusted, without pressing the cylindrical lens **115** against the cylindrical lens pressing section **138**. The cylindrical lens **115** is then bonded and fixed to the holder **130** at the cylindrical lens bonding sections **134**.

## Embodiment 3

An optical head according to a third embodiment of the present invention will be explained next.

FIGS. **20**A to **20**C illustrate the configuration of the detector unit **127** provided in the third embodiment. The figure illustrates the light detector **120**, the cylindrical lens **115**, the holder **130**, the aperture **131**, the four-quadrant light-receiving region **140** and sub-beam light-receiving regions **141**.

The third embodiment differs from the first embodiment in that herein the shape of the aperture **131** is not cylindrical, but non-cylindrical. The four-quadrant light-receiving region **140** and sub-beam light-receiving regions **141** are disposed on the light-receiving surface **121** of the light detector **120** in such a way as to be arrayed in one direction, and the aperture **131** is shaped in such a manner that the cross-sectional shape thereof extends in that direction as a non-cylindrical shape. The non-cylindrical shape of the aperture allows reducing the amount of other-layer stray light that strikes the light-receiving surface **121**, and allows realizing yet more stable focus servo and tracking servo.

The aperture **131** in the third embodiment is shaped as a rectangle, but may also be shaped as long hole whose peripheral face is shaped in part as a circular arc, or may be shaped as an oval or the like, as shown in FIG. **20**D.

## Embodiment 4

An optical head **200** according to a fourth embodiment of the present invention will be explained next.

The shape and arrangement of the aperture **131** in the fourth embodiment are different from those in the first to third embodiments.

FIG. **21**A illustrates the configuration of an optical system of an optical head **200** according to the fourth embodiment. The semiconductor laser **101** emits a light beam having an emission wavelength of about 405 nm. In this optical system, a hologram element **150** is disposed between the beam splitter **103** and the cylindrical lens **115**. The optical head generates a tracking error signal by a one-beam method (APP method).

FIG. **21**B illustrates the configuration of the hologram element **150**. The solid line in the figure denotes a split pattern of the hologram element **150**, and the broken line indicates the cross-sectional shape of a light beam that traverses the hologram element **150**. The hologram element **150** has a main beam region **151**; APP main regions **152**, **153** onto which there strike interference light in the form of ±1 order light and 0 order light, diffracted by the information recording layer **202**; and APP sub-regions **154**, **155** onto which only 0-order light is incident.

FIGS. **22**A and **22**B illustrate schematically the relative position relationship between the aperture **131** and the light-receiving surface **121** of the light detector **120**. As illustrated in FIG. **22**A, the light-receiving section **124** of the light detector **120** comprises the circuit section **122**, the bonding layer **126** and the cover glass **125**. As illustrated in FIG. **22**B, the four-quadrant light-receiving region **140**, the APP main regions **152**, **153** and the APP sub-regions **154**, **155** are formed in the light-receiving surface **121**. The fan-shaped broken line in FIG. **22**B denotes the shape of the aperture **131**. In the present embodiment, the light-receiving surface **121** is rectangular, and the aperture **131** is fan-shaped. The central position of the fan shape is positioned in the vicinity of one of the corners of the light-receiving surface **121**.

The light beams that pass through the split regions of the hologram element **150** strike the light-receiving surface **121**. The light beam that passes through the main region **151** of the hologram element **150** strikes the four-quadrant light-receiving region **140** of the light-receiving surface **121**, while the light beams that pass through the APP main regions **152**, **153** or the APP sub-regions **154**, **155** of the hologram element **150** strike respective light-receiving regions (sub-beam light-receiving regions **141**) in the figure.

In the four-quadrant light-receiving region **140**, a focus error signal is generated through calculation of the difference between the sum signals of diagonally-opposing regions (difference between the two sum signals obtained from the diagonally-opposing regions). An RF signal is generated on the basis of the total sum of the signals for each region of the four-quadrant light-receiving region **140**. A tracking error signal is generated on the basis of a light reception signal from the sub-beam light-receiving regions **141**. That is, a so-called push-pull signal is generated on the basis of the differentials between the light beams received at the sub-beam light-receiving regions **141** (light beams passing through the APP main regions **152**, **153**). This signal is computed with the light reception signal from the light beams (light beams passing through the APP sub-regions **154**, **155**) received at the sub-beam light-receiving regions **141**. A tracking error signal is thus generated in accordance with a so-called APP method.

The four-quadrant light-receiving region **140** and the sub-beam light-receiving regions **141** are disposed spaced apart from each other on the light-receiving surface in such a manner that other-layer stray light does not strike the sub-beam light-receiving regions **141**. To achieve a thinner optical head **200**, the four-quadrant light-receiving region **140** and the sub-beam light-receiving regions **141** are disposed on the light-receiving surface **121**, not along a straight line but forming an L. Specifically, the four-quadrant light-receiving region **140** is disposed in the vicinity of one corner of the rectangular light-receiving surface **121**, one sub-beam light-receiving region **141** is disposed in the vicinity of a corner that is adjacent to the above corner, and a further sub-beam light-receiving region **141** is disposed in the vicinity of the other corner that is adjacent to the first corner. In such an arrangement, the center of the optical axis coincides with the center of the four-quadrant light-receiving region **140**. In other words, the barycenter positions of the four-quadrant light-receiving region **140** and the sub-beam light-receiving regions **141**, **141** are offset with respect to the position of the optical axis center (center position of the aperture **131**) and with respect to the barycenter position of the light-receiving surface **121**.

In the first embodiment, the aperture **131** and the light-receiving surface **121** of the light detector **120** are disposed in such a manner that the center (optical axis center) of the four-quadrant light-receiving region **140** coincides with the center of the aperture **131**. In the fourth embodiment, by contrast, the aperture **131** is fan-shaped (non-circular), and the center of the fan shape of the aperture **131** does not coincide with the center of the four-quadrant light-receiving region **140** (center of the light beam that passes through the main beam region **151**). Such a configuration allows reducing to the utmost the aperture **131** with respect to the four-quadrant light-receiving region **140** and the sub-beam light-receiving regions **141**, **141**. In turn, this allows reducing significantly the quantity of other-layer stray light that strikes the light-receiving surface **121**, as well as the stray light that arises on account of, for instance, surface reflection in the optical elements. Focus error signal offset and tracking error signal offset can both be significantly reduced thereby, and the optical head **200** can be made significantly thinner.

An explanation follows next, with reference to FIG. **22**C, on stray light that strikes the four-quadrant light-receiving region **140**, the sub-beam light-receiving regions **141** and the bonding layer **126**. FIG. **22**C, illustrates, by way of arrows, the stray light that is reflected by the surface of the optical disk **201**, the surface of the optical elements, the surface of the optical base **113** and so forth. Stray light can be easily blocked by sites other than the aperture **131** of the holder **130**, by bringing the peripheral edge of the aperture **131** close to the four-quadrant light-receiving region **140** and the sub-beam light-receiving regions **141**. Stray light that strikes the four-quadrant light-receiving section region **140** and the sub-beam light-receiving regions **141** can be significantly reduced thereby.

The bonding performance of the bonding layer **126** is impaired after several hundred hours of irradiation by light beams having a 405 nm wavelength. In the present embodiment, therefore, the bonding layer **126** is covered and hidden entirely by the holder **130** in such a manner that the bonding layer **126** does not protrude into the aperture **131**. The adhesive is positioned in the vicinity of the peripheral edge of the rectangular light-receiving surface **121** in the light-receiving section **124**, as illustrated in FIG. **22**B. The peripheral edge of the aperture **131**, as viewed from the optical axis direction, is positioned further inward than the inner edge of the adhesive, as illustrated in FIG. **22**C. As a result, the bonding layer **126** is prevented from being struck by light beams having a 405 nm wavelength. The holder **130** blocks other-layer stray light that strikes mainly the scattering system, and blocks also stray light that is reflected at the surface of the optical disk **201**, the surface of the optical elements, the surface of the optical base **113** and so forth, and that strikes mainly the condensing system.

The above configuration allows suppressing degradation of the bonding layer **126** that is caused by irradiation of a light beam having a wavelength of about 405 nm. The reliability of the optical head **200** can be significantly enhanced as a result.

## Embodiment 5

A fifth embodiment of the present invention is explained next.

FIGS. **23**A and **23**B illustrate the configuration of an optical system provided in an optical head **200** according to a fifth embodiment of the present invention. The fifth embodiment differs from other embodiments in that herein the cylindrical lens **115** is inclined with respect to the light-receiving surface **121** of the light detector **120**.

As illustrated in FIG. **23**A the light beam emitted by the semiconductor laser **101**, as a light source, is split into a plurality of light beams by the diffraction grating **102**. The light beams that pass through the diffraction grating **102** are reflected by a flat-plate beam splitter **160**, and are converted into parallel light beams by the collimator lens **104**, and then are incident on the objective lens **105**. As a result, the light beams become so-called three-beam converging light that is irradiated onto the optical disk **201**.

An objective lens actuator drives the objective lens **105** in the optical axis direction (focus direction) and in the radial direction of the optical disk **201**. Light reflected/refracted by the information recording layer **202** of the optical disk **201** passes again through the objective lens **105**, and through the flat-plate beam splitter **160**. The light beams that traverse the flat-plate beam splitter **160** pass through the cylindrical lens **115**, and strike the light detector **120**.

Herein, the cross section of the holder **130** is shaped as a wedge such that the first main face (cylindrical lens pressing section) of the holder **130** constitutes an inclined face **158** that is inclined with respect to the second main face (light detector pressing section). Therefore, the plane perpendicular to the lens optical axis **118** of the cylindrical lens **115** is inclined by an angle θa with respect to the light-receiving surface **121** of the light detector **120**. The holder **130** is disposed in such a manner that the inclination of the first main face is contrary to the direction in which the flat-plate beam splitter **160** is inclined.

The angle θa is set in order to correct the coma aberration of reflected light beams. An optimal value of the angle θa can be set in accordance with the angle and thickness of the flat plate-shaped optical element that is disposed in the detection optical system. The inclination angle θa preferably ranges from about 5 to 20 degrees, more preferably from about 5 to 15 degrees. In the present Embodiment 5, for instance, the inclination angle θa is of 9.5 degrees. The inclination angle θa of the cylindrical lens **115** can be appropriately set, within the above ranges, in accordance with the thickness of the beam splitter **160**, i.e. in accordance with the degree of aberration caused by the beam splitter **160**.

In the first embodiment that uses the beam splitter **103**, the angle θb of the orientation of the central generatrix **119** of the cylindrical surface **116**, in the peripheral direction, is 45 degrees. In the fifth embodiment, which uses the flat-plate beam splitter **160**, the angle θb of the orientation of the central generatrix **119** of the cylindrical surface **116**, in the peripheral direction, is set to about 40 degrees to 30 degrees with respect to the axis in direction X of FIG. 23A, in order to cancel the astigmatism generated by the light beams as the latter pass through the flat-plate beam splitter **160**. Direction X in FIG. **23**A is the direction along which the thickness of the holder **130** decreases gradually.

FIGS. **24**A to **24**C illustrate the configuration of the detector unit **127** provided in the optical head **200** of the fifth embodiment. The detector unit **127** comprises the light detector **120**, the holder **130** having the aperture **131**, and the cylindrical lens **115**. The light detector **120** is fixed to the holder **130**, and the cylindrical lens **115** is fixed pressed against the inclined face **158** of the holder **130**. The lens optical axis **118** of the cylindrical lens **115** is fixed thereby at an inclination angle that is just the angle, with respect to the optical axis of the reflected light beam, at which coma aberration is cancelled. The above configuration allows reducing significantly coma aberration caused by the light beams that pass through the flat-plate beam splitter **160**, and allows improving the quality of the light beams that strike the light detector **120**. That is, the above configuration allows enhancing focus error signal, tracking error signal and RF signal detection performance.

The central generatrix **119** of the cylindrical surface **116** of the cylindrical lens **115** is fixed at the center of the lens optical axis **118** of the cylindrical lens **115**, but rotated by the angle θb with respect to the axis in direction X, in the light-receiving surface **121** of the holder **130** or the light detector **120**. The above configuration allows canceling astigmatism generated upon passage of the light beams through the flat-plate beam splitter **160**, and allows thus reducing significantly the astigmatism of the light beams that strike the light-receiving surface **121**.

As a result, focus error signal, tracking error signal and RF signal detection performance can be enhanced yet further, so that there can be realized stable focus servo and tracking servo, while significantly improving both recording and reproduction performance.

Embodiment 6

An optical head **200** according to a sixth embodiment of the present invention will be explained next.

FIGS. **25**A and **25**B illustrate a bonded state of the optical base **113** and the detector unit **127** provided in the sixth embodiment. The sixth embodiment differs from the first embodiment in that now holder supplementary bonding sections **161** are provided at different faces from those of the holder bonding sections **139**, so that there are three or more bonding sections between the holder **130** and the optical base **113**. The holder bonding sections **139** are disposed at two sites.

FIGS. **25**A and **25**B illustrate the holder bonding sections **139** and holder supplementary bonding sections **161**, as the bonding sections between holder **130** and the optical base **113**. A through-hole **113*a*** is formed in the optical base **113**, running through the latter in the thickness direction. The holder **13** has a portion that is inserted into the through-hole **113*a***, and a portion positioned at one side with respect to the optical base **113**. The portion positioned at one side with respect to the optical base **113** is fixed to the optical base **113** by way of the holder bonding sections **139**. The portion inserted into the through-hole **113*a*** is fixed to the optical base **113** by way of the holder supplementary bonding sections **161**.

In the first embodiment, an adhesive is coated onto two sites each, left and right, of the holder **130**, such that the holder **130** is fixed to the optical base **113** at these bonding sections **139**. In the case of an integral detector unit **127** having the above bonding structure, the weight of the cylindrical lens **115** gives rise to moment, about the holder bonding sections **139**, that acts in a direction perpendicular to the paper. As a result, the detector unit **127** may become tilted, about the holder bonding sections **139**, in a direction perpendicular to the paper (gravity direction). The optical axis becomes inclined in such a case, which may impair the focus and tracking servo signals as well as the RF signal.

In the sixth embodiment, the holder supplementary bonding sections **161** are disposed at positions in the optical axis direction (direction Z) that are different from those of the holder bonding sections **139**, as illustrated in FIGS. **25**A and **25**B. Such a configuration allows significantly stabilizing the fixing of the holder **130** against the optical base **113**, and allows reducing the inclination of the holder **130** and the detector unit **127** with respect to the optical base **113**. A small optical head **200** having excellent reliability can be realized thus by preventing the detector unit **127** from tilting with respect to the optical axis direction.

In the sixth embodiment, the holder **130** is larger in the optical axis direction, and the holder supplementary bonding sections **161** are provided between the optical base **113** and the holder **130**. Alternatively, however, the holder supplementary bonding sections **161** may be provided between the cylindrical lens **115** and the optical base **113**, as illustrated in FIG.

25C. In this latter configuration, the holder **130** is shaped as a flat plate that does not jut into the through-hole **113***a* of the optical base **113**. Instead, the cylindrical lens **115** is disposed inside the through-hole **113***a*. The bonding sites may be different, or further bonding sites may be provided, so long as the bonding sites cancel the moment generated by the weight of the cylindrical lens **115**.

## Embodiment 7

An optical head **200** according to a seventh embodiment of the present invention will be explained next.

In the fifth embodiment, a light beam from the semiconductor laser **101**, as a light source, strikes the light detector **120**. In the optical head **200** of the seventh embodiment, a light beam from a semiconductor laser **409**, as a first light source, strikes the light detector **120**, and also a light beam from a semiconductor laser **408**, as a second light source, strikes the light detector **120**, as illustrated in FIG. **26**.

The semiconductor laser **409**, as the first light source, is for instance a semiconductor laser that emits a light beam having a 405 nm wavelength. The semiconductor laser **408** as the second light source is a two-wavelength semiconductor laser that can emit, for instance, a light beam at a 780 nm wavelength and a light beam at a 650 nm wavelength.

In addition to the light sources **408**, **409**, the optical head **200** of the seventh embodiment comprises the diffraction grating **102**, the beam splitter **103**, the collimator lens **104**, the objective lens **105**, the flat-plate beam splitter **160**, the hologram element **150**, the cylindrical lens **115**, the holder **130** and the light detector **120**. The beam splitter **103** reflects the light beam emitted by the semiconductor laser **408**, and the beam splitter **160** reflects the light beam emitted by the semiconductor laser **409**. The hologram element **150** is disposed between the flat-plate beam splitter **160** and the cylindrical lens **115**.

Herein, the cross section of the holder **130** is shaped as a wedge such that the first main face (cylindrical lens pressing section) of the holder **130** constitutes an inclined face **158** that is inclined with respect to the second main face (light detector pressing section) of the holder **130**. Therefore, the plane perpendicular to the lens optical axis **118** of the cylindrical lens **115** is inclined by an angle θa with respect to the light-receiving surface **121** of the light detector **120**. The holder **130** is disposed in such a manner that the inclination of the first main face is contrary to the direction in which the flat-plate beam splitter **160** is tilted.

## Embodiment Overview

The above embodiments can be summarized as follows.

(1) The optical head in the above embodiments comprises a light source that emits a light beam; an objective lens that condenses, in the form of converging light, the light beam emitted by the light source, onto an information recording medium; a cylindrical lens, onto which a reflected light beam that is reflected by the information recording medium is incident, and which generates astigmatism for forming a focus error signal; a light detector that receives the reflected light beam passing through the cylindrical lens; and a holder that holds the cylindrical lens and the light detector; wherein the holder has a first main face and a second main face that extend in directions that intersect the optical axis of the reflected light beam, and the cylindrical lens is bonded to the first main face and the light detector is bonded to the second main face.

In the above configuration, the cylindrical lens and the light detector are constructed integrally with the holder. The relative positional error between the cylindrical lens and the light detector can be reduced thereby. This allows reducing, as a result, errors and changes in detection magnification (lateral magnification) in the detection optical system.

Also, it is possible to adjust the position of the light detector and the cylindrical lens integrally in two perpendicular directions, within a plane that is perpendicular to the light beam that is incident on the light detector, and to adjust the rotation direction of the light detector and the cylindrical lens. The relative positional error between the cylindrical lens and the light detector can be further reduced as a result.

(2) In a case where the optical head further comprises a collimating lens that modifies parallelism of the light beam from the light source, a lateral magnification of a detection optical system that comprises the objective lens, the collimating lens and the cylindrical lens, is preferably equal to or greater than 10 times. In this case, preferably, the cylindrical lens has a cylindrical surface on the surface at which the reflected light beam is incident, and a concave lens surface at an exit surface.

The above configuration allows suppressing tracking error signal offset that arises when reflected light from a layer other than the information recording layer strikes a sub-beam light-receiving region during recording and reproduction to/from a multilayer optical disk. As a result, tracking servo performance can be made more stable during recording and reproduction to/from a multilayer optical disk.

The relative positional error between the cylindrical lens and the light detector is reduced by constructing the cylindrical lens and the light detector integrally with each other. As a result there can be realized large detection magnification (lateral magnification) in a detection optical system suitable for multilayer optical disks.

The magnification of the detection optical system can be increased, and the dimensions of the detection optical system made shorter, by conferring a significant concave lens effect to the cylindrical lens. Doing so allows realizing stable tracking servo, suitable for multilayer optical disks, while reducing the size of the optical head.

Further, a focus error signal having good balance can be obtained, also in a small detection optical system, by arranging the cylindrical surface at the opposite side away from the light detector. Stable focus servo can be realized as a result, and a comparatively large astigmatic difference can be secured as well, which in turn allows obtaining a focus error signal having a long acquisition range.

The cylindrical surface is exposed outside upon assembly of the detector unit. Therefore, the orientation of the central generatrix of the cylindrical surface can be easily detected and adjusted, by way of an auto-collimator or the like, during adjustment of the direction of the central generatrix of the cylindrical surface with respect to the split directions of the light-receiving region of the light detector. The adjustment time of the optical head can be significantly shortened as a result.

The cylindrical lens and the light detector can be adjusted integrally together in direction Z (optical axis direction). This allows reducing magnification changes in the detection optical system, and allows realizing stable recording and reproduction performance in the optical head, with small fluctuation in tracking error signal offset.

(3) The radius of curvature of the concave lens surface may be equal to or smaller than 5 mm.

(4) The cylindrical lens may have a flat surface formed at the exit surface, in addition to the concave lens surface.

In the above configuration, the cylindrical lens is bonded and fixed in a state where a flat surface of the cylindrical lens is closely attached to the holder. This allows realizing a highly reliable optical head. The rotation adjustment of the cylindrical lens can be performed in a shorter time, with high precision, by arranging the cylindrical surface on the side of the incidence surface. This allows realizing an optical head that delivers excellent performance.

(5) Preferably, an aperture is formed in the holder at a position at which at least part of the reflected light beam is incident. Such a configuration allows a light beam that traverses the cylindrical lens to strike the light detector after passing through the aperture in the holder.

Also, the cylindrical lens, the light detector and the holder can be moved integrally together during adjustment of the positions of the cylindrical lens and the light detector. This allows reducing the relative positional offset between the cylindrical lens, the aperture and the light detector, in the optical axis direction and in directions that are perpendicular to the optical axis direction. The aperture diameter can be reduced thereby, which in turn allows reducing the amount of stray light leakage, onto the light detector, from stray light arising from reflection of light beams onto other layers, in particular during recording and reproduction of information in multilayer optical disks. As a result, recording and reproduction performance can be enhanced while using a smaller, thinner holder. A smaller, thinner optical head can thus be realized thereby.

(6) Preferably, the aperture has a dimension corresponding to a value that results from adding a dimension of the reflected light beam, a relative positional error between the cylindrical lens and the aperture, a relative positional error between the light detector and the aperture, and an increase in the dimension of the reflected light beam at the position of the aperture resulting from integrally adjusting the holder, the cylindrical lens and the light detector in an optical axis direction.

(7) The aperture may have a non-circular cross section.

(8) The center of the aperture may be disposed at a position different from the center of the optical axis of the reflected light beam. Such a configuration allows reducing the size of the aperture, which in turn allows reducing the amount of stray light that reaches the light detector.

(9) The surface roughness of the second main face to which the light detector is bonded may be smaller than the surface roughness of a side face of the holder. This configuration enables fine motion during adjustment of the position of the light detector, and makes for more precise positioning.

(10) The surface roughness of a predetermined region of the second main face including a central portion may be smaller than the surface roughness of an outer peripheral region of the predetermined region in the second main face. This configuration enables fine motion during adjustment of the position of the light detector, and makes for more precise positioning.

(11) The surface roughness of the first main face to which the cylindrical lens is bonded may be smaller than the surface roughness of a side face of the holder. This configuration enables fine motion during adjustment of the position of the cylindrical lens, and makes for more precise positioning.

(12) The surface roughness of a predetermined region of the first main face including a central portion may be smaller than the surface roughness of an outer peripheral region of the predetermined region in the first main face. This configuration enables fine motion during adjustment of the position of the cylindrical lens, and makes for more precise positioning.

(13) The first main face to which the cylindrical lens is bonded may be inclined relative to a face that is perpendicular to the optical axis of the reflected light beam. The above configuration allows reducing significantly coma aberration caused by the light beam that passes through the flat plate beam splitter, and allows improving the quality of the light beams that strike the light detector.

(14) In a case where the light source emits a light beam having a wavelength of about 405 nm and the light detector has a light-receiving section, a cover glass, and a bonding section that bonds the light-receiving section and the cover glass, then an inner end portion, of the bonding section, that bonds the light detector and the second main face, or an inner end portion, of the bonding section, that bonds the light-receiving section and the cover glass, may be disposed further outward than the aperture. This configuration allows suppressing adhesive deterioration that is caused by irradiation of a light beam having a wavelength of about 405 nm. The reliability of the optical head can be significantly enhanced as a result.

(15) The optical information device comprises the optical head; a transport unit for transporting the optical head; and a control circuit for controlling the transport unit and the optical head.

## INDUSTRIAL APPLICABILITY

The optical head device and optical information device according to the present invention boast stable tracking control performance and can realize low information error rates, and are thus useful, for instance, in external recording devices in computers that have stable recording and reproduction performance. The optical head device and optical information device according to the present invention can be used in various applications such as video recording devices and video reproduction devices, for instance DVD recorders, BD recorders and HD-DVD recorders. The invention can also be used in recording devices of car navigation systems, portable music players, digital still cameras and digital video cameras.

The invention claimed is:

**1**. An optical head, comprising:

an optical base;

a light source that emits a light beam;

an objective lens that condenses, in the form of converging light, the light beam emitted by said light source, onto an information recording medium;

a cylindrical lens, onto which a reflected light beam that is reflected by the information recording medium is incident, and which generates astigmatism for forming a focus error signal;

a light detector that receives the reflected light beam passing through said cylindrical lens; and

a holder that holds said cylindrical lens and said light detector, said holder having a first main face and a second main face that extend in directions that intersect an optical axis of the reflected light beam,

wherein said cylindrical lens is bonded to said first main face and said light detector is bonded to said second main face,

wherein said holder is held by said optical base while said holder is configured to be adjusted in position with respect to said optical base in three perpendicular directions in a state that said cylindrical lens and said light detector are bonded to said holder,

wherein an aperture is formed in said holder at a position at which at least part of the reflected light beam is incident,

wherein said aperture has a dimension corresponding to a value that results from adding a dimension of the reflected light beam, a relative positional error between said cylindrical lens and said aperture, a relative positional error between said light detector and said aperture, and an increase in the dimension of the reflected light beam at the position of said aperture resulting from integrally adjusting said holder, said cylindrical lens and said light detector in an optical axis direction.

**2**. The optical head according to claim **1**, further comprising:

a collimating lens that modifies parallelism of the light beam from said light source,

wherein a lateral magnification of a detection optical system that comprises said objective lens, said collimating lens and said cylindrical lens is equal to or greater than 10 times,

and wherein said cylindrical lens has a cylindrical surface on a surface at which the reflected light beam is incident, and a concave lens surface at an exit surface.

**3**. The optical head according to claim **2**,

wherein a radius of curvature of said concave lens surface is equal to or smaller than 5 mm.

**4**. The optical head according to claim **3**,

wherein said cylindrical lens has a flat surface formed at said exit surface, in addition to said concave lens surface.

**5**. The optical head according to claim **1**,

wherein said aperture has a non-circular cross section.

**6**. The optical head according to claim **5**,

wherein the center of said aperture is disposed at a position different from the center of said optical axis of the reflected light beam.

**7**. The optical head according to claim **1**,

wherein a surface roughness of said second main face to which said light detector is bonded is smaller than a surface roughness of a side face of said holder.

**8**. The optical head according to claim **1**,

wherein a surface roughness of a predetermined region of said second main face including a central portion is smaller than a surface roughness of an outer peripheral region of said predetermined region in said second main face.

**9**. The optical head according to claim **1**,

wherein a surface roughness of said first main face to which said cylindrical lens is bonded is smaller than a surface roughness of a side face of said holder.

**10**. The optical head according to claim **1**,

wherein a surface roughness of a predetermined region of said first main face including a central portion is smaller than a surface roughness of an outer peripheral region of said predetermined region in said first main face.

**11**. The optical head according to claim **1**,

wherein said first main face to which said cylindrical lens is bonded is inclined relative to a plane that is perpendicular to said optical axis of the reflected light beam.

**12**. The optical head according to claim **1**,

wherein said light source emits a light beam having a wavelength of about 405 nm,

said light detector has a light-receiving section, a cover glass, and a bonding section that bonds said light-receiving section and said cover glass, and

an inner end portion, of said bonding section, that bonds said light detector and said second main face, or an inner end portion, of said bonding section, that bonds said light-receiving section and said cover glass, is disposed further outward than said aperture.

**13**. An optical information device, comprising:

the optical head according to claim **1**;

a transport unit for transporting said optical head; and

a control circuit for controlling said transport unit and said optical head.

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